Alaska Natural Gas Transportation Systems

White House Task Force
Lead Agency Report

on

Construction Delay and Cost Overruns

U.S. Department of the Interior
U.S. Department of Transportation

July 1, 1977

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Objective

The object of this report is to review the analysis and findings of the Federal Power Commission (FPC) in their Recommendation to the President: Alaska Natural Gas Transportation Systems with respect to the potential for schedule delay and cost overrun. The Commission's Findings are not fully specified, but a reasonable interpretation is presented on the following page and contrasted with the Lead Agency Findings.

Findings

This Lead Agency Report prepared by the Department of the Interior and the Department of Transportation generally agrees with the Commission's relative ranking among the projects with regard to the possibility of cost overrun and construction delay but differs sharply with respect to the magnitude of the overruns. The Federal Power Commission examined a number of sources of overrun and delay but they seemed to consider these in isolation; they did not fully evaluate the contribution of these sources collectively and interactively to their overall cost and time requirements for completing a long-term, complex construction project.

FPC FINDINGS[1]

	Arctic Gas[2]	Alcan	El Paso
Direct Cost[3]	6783[7]	5781	5588
Total Cost (Includes Financing)[3]	8147[8]	6761	6571
Full Gas Flow Realized	Jun 83	Jan 83	Nov 83
Potential Cost Overrun (%)[6]	5	5-10	7-10
Potential Delay (Months)[6]	12	9	0
Net National Economic Benefit[3,4]	7122	7652	5798
Cost of Service ($ per MCF)[5]	1.72	1.79	2.09

LEAD AGENCY FINDINGS[1]

	Arctic Gas[2]	Alcan	El Paso
Expected[10] Direct Cost Overruns[3]	2506[7]	1864	1736
(%)	(37%)	(32%)	(31%)
Expected Direct Costs[3,11]	9289	7645	7324
Expected Total Cost Overruns[3]	4317[8]	3159	2775
(%)	(53%)	(47%)	(42%)
Expected Total Costs (Includes Financing)[3]	12464	9920	9328
Expected Schedule Delay (Months)	20	17	15
Expected Full Flow Date[9]	Mar 85	July 84	Feb 85
Expected Net Nat. Econ. Benefits[3,4]	3311	4825	3908
Expected Cost of Serv. ($ / MCF)[5]	2.15	2.09	2.26

1. All values in 1975 prices; assumed January 1978 go-ahead.
2. Arctic Gas costs include Canadian share.
3. Millions of dollars.
4. Present value discounted at 10%.
5. Includes $1.00 per MCF wellhead price of gas, 20 year average.
6. No NNEB or cost of service calculations are available based on these values.
7. U. S. share of Arctic direct costs is $5.621 billion; U. S. share of Arctic direct cost overruns is approximately $2 billion.
8. U. S. share of Arctic total costs is $6.729 billion; U. S. share of Arctic total cost overruns is approximately $3.432 billion.
9. Both El Paso and Alcan have partial, but substantial, gas flows occurring 6 to 10 months earlier.
10. The expected value is the mean or "average" of the estimated probability distribution.
11. An upper bound, or "worst" case, may be estimated by adding three standard deviations to the expected value: Artic Gas - $14.3 billion, Alcan - $11.2 billion, and El Paso - $9.3 billion. The FPC estimate may be considered a reasonable lower bound.

The FPC estimates range from 5% to 10% cost overruns for the proposals; this Report estimates direct cost overruns for the various proposals ranging from about 30% to about 40%; moreover, this Report finds that overruns on total costs including financing (allowance for funds used during construction) may range from 40% to 55%. The Commissioners have estimated potential delays ranging from 0 to 12 months; this Lead Agency Report anticipates delays ranging from 15 to 17 months.

This Report indicates the Arctic Gas proposal to contain the greatest uncertainty, while the Alcan and El Paso proposals contain less. Taking expected cost overruns and construction delays into account, the report finds that the Alcan proposal has the earliest expected delivery date and the least total cost, El Paso the next earliest delivery date and higher total cost, and Arctic Gas the latest delivery date and highest total expected cost.

Procedure

These estimates were arrived at on the basis of joint estimates of expected cost overruns and schedule delays by independent analysts familiar with each of the three proposed transportation systems and the Trans-Alaska Pipeline System. The FPC estimates are plausible but optimistic engineering estimates, while those presented here recognize that few major construction projects achieve the planned performance, cost and schedule goals. These estimates should be considered "expected value" estimates. It should be noted, that the results presented here do not indicate that a natural gas transportation system is uneconomic.

Other independent analyses, including the FENCO, Inc. risk analysis of Arctic Gas and Alcan for the Canadian Ministry of Energy, Mines, and Resources, the Resource Planning Associates, Inc. risk analysis of all three proposals for the Environmental Protection Agency, and the Department of Interior Report to Congress under P. L. 93-153 have concluded that all the applicants, but particularly Arctic Gas, are quite optimistic in their proposals. The major uncertainties that the FPC failed to assess realistically are highlighted below.

Construction and Productivity

The Commission concluded that Arctic Gas and El Paso have proposed "reasonable" construction programs while questioning the Alcan estimates of productivity. This report finds that Arctic Gas has seriously underestimated the economic costs of construction during the arctic winter. El Paso has also overestimated winter pipeline construction productivity and underestimated potential problems on the complex liquefaction plant. Alcan has overestimated the productivity of its rapid summer construction program, particularly because of the difficulty in supplying the skilled manpower necessary.

Snow Roads and Work Pads

The Commission has concluded that the proposed use of snow roads and snow work pads is a "feasible" arctic construction technique. This report finds that the economic feasibility of these techniques is extremely uncertain. The FPC hearing record indicates substantial controversy over even the technical feasibility. The record further indicates less than complete agreement on the availability of adequate snow and water, particularly on the North Slope. The economic costs of a construction program relying on snow roads and snow work pads at the scale proposed by Arctic Gas -- and to a lesser extent by El Paso -- are very uncertain. There is no equivalent experience available; the concept has never been tested on a comparable scale. Alcan's construction plan avoids this risk since it relies on summer and conventional winter construction.

Construction Logistics and Transportation Corridors

The Commission found no substantial logistical problems for any of the applicants, nor did it emphasize any substantial advantage for a particular system because of its corridor. This report finds, to the contrary, that logistical problems beyond those anticipated by the applicants are highly probable.

Alyeska experience indicates that it is virtually impossible to fully predict all requirements in advance and that supporting large scale construction efforts in remote regions of the arctic is extremely difficult. It is clear that alternatives and flexibility are essential for cost and schedule control -- two elements limited in the Arctic Gas logistic plan. Arctic Gas must rely on a logistics system that is very seasonally oriented -- use of snow roads in the winter and shipping on the Mackenzie River in the summer. Both El Paso and Alcan propose routes having access to virtually all weather transportation systems and other existing infrastructure.

Seismic Design

The Commission found that El Paso has an incomplete seismic design but that adequate time had been provided in the pre-construction schedule to complete the design at "some increases" in cost. The conclusion of this report is that the incomplete design work for the liquefaction plant at Point Gravina leaves substantial uncertainty in both cost and schedule. The record indicates substantial controversy regarding what design factors are acceptable, and there is little experience in designing large scale LNG facilities for a high degree of seismic protection. El Paso is judged to have underestimated the complexity of meeting stringent seismic standards, while neither Arctic or Alcan have a significant seismic problem.

Frost Heave/Thaw Settlement

The Commission concluded that there is ". . . no doubt that an adequate solution can be found . . ." although with ". . . sufficient expenditure of design, time and capital". This report concludes that the applicants may well have substantially underestimated the required design, time and capital.

The exact nature of the technical solution to frost heave/thaw settlement is still an unknown; some experts believe that portions of a gas line may have to be elevated. The economics of an as yet unproven solution are extremely difficult to estimate, particularly if it involves a relatively complex technology (e.g., electrical heating or buried supports).

Project Management and Scheduling

The Federal Power Commission did not address itself specifically to the question of management and scheduling although it did conclude that Arctic Gas and El Paso had presented reasonable programs for executing feasible projects. This report finds project management and scheduling to be a crucial element in completing any of these large, complex, and remote projects in a timely and economic manner. The Alyeska experience is replete with situations where a problem in one area spilled over into other areas. All of the proposals contain large numbers of interactive elements for which a difficulty with one activity will adversely affect progress on another -- resulting in possible delays. All of the projects contain a number of techniques which are relatively unproven in regular commercial application. The projects, through sheer magnitude, will draw on both labor and vendors having limited previous experience in this work.

Institutional Uncertainties

The FPC generally concluded that the applicants had allotted sufficient time during their pre-construction and construction phases to allow for resolution of a number of institutional issues. This report finds that several institutional issues pose major problems for the applicants, with substantial probability for schedule delay and cost overrun. Joint U. S.-Canadian decisions for Arctic Gas and Alcan have the potential for causing delays. Site selection and approval for El Paso's regasification terminal in California may cause some delay. Final right-of-way determination for all applicants is currently on an uncertain schedule. Governmental stipulations, regulations, and permits during construction by any applicant could cause construction delays. Finally, resolution of Canadian Native Claims is likely to cause significant delay for Arctic Gas and, to a lesser extent, Alcan.

Other Large Scale Construction Project Experience

Studies by Professor Mead and others indicate that the ability to accurately forecast the cost of large complex construction projects is very limited. Examples of such evidence are numerous and include Trans-Alaska Oil Pipeline (TAPS), North Sea Oil production, Trans-Peru Pipeline, METRO and Canadian Olympic facilities. These studies indicate that for construction projects involving long construction periods, new technology applications, extensive geotechnical work, and activity in remote areas, costs and schedules substantially beyond those estimated have almost always occurred and are likely to occur in the future.

Probably the most comparable projects is the TAPS project. An early, reliable cost estimate is considered to be the May 1974 estimate of $4.088 billion. In June 1975, a final, detailed estimate was made at $6.375 billion and now, only two years later, the final cost is expected to be at least $7.815 billion -- a 23% overrun, excluding financing. In comparison, this Report estimates 30 to 40% cost overruns, excluding financing, for projects 4 to 7 years away from completion.

Operating Risks

This Lead Agency Report finds uncertainties and their economic impact to be less significant during the operating phase than during the pre-construction and construction phase. The risks of flow interruption and cost overruns during operations is greatest for El Paso because of its complex nature and seismic risk (a major earthquake in the vicinity of the liquefaction site could cause interruption of weeks to more than a year) while both Alcan and Arctic Gas are considered low risk.

I. INTRODUCTION

A. Background

The object of this report is to review the analysis and findings of the Federal Power Commission, in their Recommendation to the President: Alaska Natural Gas Transportation Systems, with respect to the potential for schedule delay and cost overrun. The Commission's conclusions regarding these risks are not completely clear, but a reasonable interpretation is presented in Table 1.

TABLE 1

FPC RISK SUMMARY

	Applicant Capital Cost w/o AFUDC ($ Millions)	FPC Potential Cost Increase % (Total Cost)	Applicant Construction Completion Sched (Months from Go-Ahead)	FPC Potential Delay (Months)
Arctic Gas	6,783.0	5% (7,122)	66	Some probability of 12 months
El Paso	5,587.5	7-10% (6,146.3)	70	High probability of no delay
Alcan	5,780.0	5-10% (6,359.0)	60	High probability of 9 months

In order to critically analyze the FPC report, this study also reviewed other existing information related to the possibility and impact of construction delays and cost overruns (including construction schedules, capital and operating costs and reliability of estimates) to arrive at a relative judgment concerning the eventual total system cost for each of the three transportation systems.1/ The major emphasis is on the construction phase, rather than on the operating phase, of the projects reflecting the concerns in the existing record and the greater uncertainty associated with construction. This report describes these risks in terms of their economic consequences. As such, it addresses the two major economic risks during the construction phase, which are schedule delays and cost overruns, and the two major economic risks during the operation phase, which are flow interruptions and cost overruns. In addition the report covers implications of cost overruns for net national economic benefits (NNEB) and cost of service. Schedule delays and cost overruns during construction have three major economic impacts: the direct out-of-pocket cost involved; the additional interest on the borrowed money that accumulates, i.e., allowance for funds used during construction (AFUDC); and the revenues foregone during any delay in project startup. Similarly, there are two major economic impacts of flow interruptions and cost overruns during the operation of the project: the direct out-of-pocket cost involved and the lost revenues during an interruption in the project.

1/ The information reviewed included the risk analyses prepared by Arctic Gas and Alcan for the National Energy Board of Canada.

The essence of an economic risk analysis is an assessment of the uncertainty surrounding the economic parameters of a project. A common confusion, evident in the record, is between economic uncertainty and technical uncertainty; these are two different but dependent issues. Even when we have a high degree of confidence in our technical ability to do something -- which may well be the case with the gas pipeline, we may still find ourselves unable to do it economically -- such that the revenues or benefits justify the costs. It is a long step from demonstrating limited technical feasibility in a small scale demonstration under "pilot study" conditions to guaranteeing economic feasibility for a large scale effort under field conditions.

Despite the conclusions drawn by the Administrative Law Judge and the Federal Power Commission, it is clear from the record that substantial economic and some technical uncertainty continue to exist at this time for all three of the transportation systems. For instance, Chapters 7 and 8 of the Commission's Recommendation to the President refer to some twenty-five remaining technical and economic uncertainties. Regardless of the applicant's assurances, consideration of these uncertainties merits an important position in the federal decision-making process.

Economic risk analysis of cost overruns and time delays is rooted in uncertainty. It is difficult and, in some cases, statistically invalid to make a precise statement about the outcome of any one event (e.g., there will or will not be enough snow for snow roads on the North

Slope by October 16 of the year construction has been scheduled). This involves combining judgments on a large number of component events, some of which are related to each other, into an overall judgment. The overall outcome is only distantly related to that of an individual event.

B. Risk Assessment Methodology

The approach used in this report to estimate expected values for schedule delays and cost overruns is based on a process of subjective probability assessment by a number of individuals familiar with the proposed systems.[1/] Prior to the actual estimation, discussions were held during which a common set of assumptions for each of the proposed systems was established. Further preliminary discussions addressed the explicit procedures for probability estimation and the problems involved.[2/]

1/ These individuals include representatives of the Department of Transportation and the Department of the Interior, the two departments having the major responsibilities for the review and approval of the TAPS. Participating representatives from the DOI have had continuing involvement with the Alaskan Gas applications for over two and a half years and were the principal investigators for the *Alaskan Natural Gas Transportation Systems: A Feasibility Study*. These lead agencies were assisted by: The Aerospace Corporation (a Federal Contract Research Center) who also supported the aforementioned study and is currently conducting a study for the State of Alaska of TAPS cost history and an economic analysis of the natural gas transportation applicants; Resource Planning Associates who have prepared a study for EPA entitled *Risk Assessment of Alternative Alaskan Natural Gas Transportation Systems* and are also studying the TAPS cost history for the State of Alaska; VHS Associates who participated on the DOI and State of Alaska studies; and Einar Skinnarland of Terminus Limited of Toronto, Ontario, an arctic construction consulting firm involved in varying capacities with TAPS since 1973; Jack Faucett Associates, an economic consulting firm to various government agencies on energy issues.

2/ E. C. Capen, "The Difficulties of Assessing Uncertainty", The Journal of Petroleum Technology, August 1976.

The subjective probabilities were derived by asking each individual to estimate three probability percentiles for schedule delays and cost overruns for each system:

(1) the median - that value for which the individual believes there is a 50% chance that the actual, realized value will fall below,

(2) the 5% confidence level - that value for which the individual believes there is only a 5% chance that the actual, realized value will fall below, and

(3) the 95% confidence level - that value for which the individual believes that there is a 95% chance that the actual, realized value will fall below.

The individual estimates for each of these three values are then averaged (with equal weight) to arrive at a group judgment for the three percentiles (Appendix B). Schedule dealys and cost overruns were estimated simultaneously because to a large degree, project management may substitute cost overrun for schedule delay. The simultaneous estimates represent, in effect, two observations from a joint probability distribution.

Given then the group judgment for each of the percentiles, two relatively distribution-free (no assumptions regarding the form of the probability distributions are required) statistical formulas are used to approximate the expected values and standard deviations for schedule delay and cost overrun [3/].

This process does not have the aura of precision that traditional engineering cost estimates have. However, it is the shortcomings of the engineering cost estimating for complex long lead time projects that we are attempting to overcome. The use of expert judgment to directly assess uncertainty is a well-accepted approach in decision analysis; in this case, it is the only way that we can incorporate explicitly our judgments concerning the "unknown" unknowns -- i.e., those problems which inevitably arise on any project incorporating any unprecedented aspect and thus cannot be specifically earmarked.

3/ Perry and Greig, "Estimating the Mean and Variance of Subjective Distributions in PERT and Decision Analysis", The Journal of Management Science, August 1975.

C. Historical Experience

Any attempt to predict the future must rely to a great extent upon an analysis and understanding of past experience. To this end, a number of formal studies have analyzed the ability to forecast the schedules and costs of complex projects and the results are not encouraging that the future can always be predicted with acceptable reliability. They indicate that key elements in project cost and schedule overruns are the length of time involved in project execution, the amount of work affected by geotechnical properties, and the amount of new technology or methods required. The proposed gas transportation systems under consideration score highly in all three areas.

A fundamental problem in major new undertakings is that engineering cost and schedule estimates seem to slight the extent of problems that, while not currently and precisely identifiable, are apt to occur in long-term, complex projects. There also are, many times, underlying reasons why initial estimates will tend to be biased downward, these estimates are used for competitive advantage or for justification for a project to proceed. Both of these underlying reasons are best supported with lower estimates. Often an additional shortcoming of the traditional engineering estimates is that they fail to consider the complex and compounding interaction of problems as they develop and tend to treat them as independent, individual events. As a result, the general historical experience, which comes to the public's attention, is one of unanticipated schedule delays and cost overruns.

Alyeska Experience

The Trans-Alaska Oil Pipeline System's (TAPS) current estimated final construction cost for the 1.2 million barrel per day design capacity is $7.7 billion. This includes a 48 inch pipeline, 12 pump stations and a marine terminal facility. The costs do not include allowance for funds used during construction (AFUDC).

In May 1974 an estimate was prepared which set the cost of TAPS at $4 billion. This incorporated the increase in design flow to 1.2 billion barrels per day. In October 1974, a revised estimate appeared which totalled $6 billion. The last estimate which Alyeska published was the June 1975 control estimate which totalled $6.375 billion. All subsequent estimates of final costs are forecasts from that base control estimate. This estimate was based on a detailed review as of April 30, 1975, of all categories of expenditures necessary to complete the project by late 1977 to an initial design capacity of 1.2 million barrels per day. The estimate included provision for escalation of the costs of labor, material, equipment and consumables, but did not include capitalized interest or contingencies.

Alyeska Pipeline Service Company often stated that it was difficult to project the ultimate cost because of variables such as: productivity of labor and equipment under Arctic conditions, availability of skilled labor in the necessary disciplines, abnormal weather conditions, possible dealys caused by unauthorized work stoppages, delays in obtaining specific construction permits, and changes that could result from encountering unforeseen geologic data. The final cost is expected to be at least $7.815 billion excluding financing.

<u>Other Large Scale Projects</u>

The purpose of this section is to provide a general appreciation of the potential for cost overrun on large scale complex projects. Professor Walter J. Mead of the University of California has prepared a general analysis based on the historical experience with sixteen major projects involving new technology. While the project sample might have included more or different projects, it is generally representative of the cost of overrun which can occur in this type of project. Mead's observations follow. 1/

"On the assumption that the best estimate of probable construction cost overruns on an Alaskan gas pipeline should be based upon the history of cost overruns on similar projects, the historical record of sixteen large construction projects has been examined. They are listed in Table 2. Some of these projects involve new technologies such as nuclear plants. Some involve old technologies but in entirely new environments, such as the Trans-Alaskan pipeline (Alyeska). None of the sixteen are military projects. Most but not all of the projects have been completed. The construction periods run all the way from three years, in the case of the Dulles Airport, to fourteen years in the case of the Bay Area Rapid Transit System. Initial capital cost estimates vary from a low of $6.1 million, in the case of the Arkansas Frying Pan Sugar Loaf Dam Project, to $2.5 billion in the case of the Washington, D. C. Metropolitan Transit Authority.

"In appraising the historical record of construction cost overruns, adjustments must be made in the initial cost estimate to correct for items. First, inflation, in addition to the anticipated level of inflation included in the initial cost estimate, must be accounted for. This unanticipated level of inflation has been computed and added to the initial cost estimate.

1/ Walter J. Mead, "Arctic Natural Gas Pipeline Alternatives", (review draft), March 1977, Chapter VI.

Table 2 -- Analysis of cost overruns in major construction projects since 1956, adjusted for (1) unanticipated inflation and (2) changes in project scope.) (million dollars)

Project	Initial cost estimate Amt.	Est. date	Latest est., or observed costs Amt.	Date	Unadjusted ratio of observed to "final" cost	Ratio adjusted Unanticipated inflation	Change in scope of proj.	Compound annual rate of cost overruns — after adjustments
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. BART-Bay Area Rapid Transit Authority	$996.0	1962	1640.0	5-76	1.647	1.297	1.037	0.31
2. New Orleans Superdome	46.0	1967	178.0	7-75	3.870	3.217	3.219	15.73
3. Wash. D.C. Area Metropolitan Transit	2500.0	1968	5020.0	5-76	2.008	1.375	1.151	0.94
4. Clinch River liquid metal fast breeder reactor (TVA)	699.0	1970	1950.0	4-76	2.790	2.384	2.384	9.08
5. Allied Chemical's Barnwell S.C. nuclear waster recycle plant.	98	1971	250.0	9-76	2.551	2.051	1.762	11.99
6. Toledo Edison's Davis-Besse nuclear power plant, Ohio	305.7	1971	466.0	5-75	1.524	1.401	1.401	11.89
7. Metroplitan Atlanta Rapid Transit Authority	1320.0[1]	1971	2100.0[1]	5-76	1.591[1]	1.257	1.108	1.03
8. Trans Alaskan Oil Pipeline (Alyeska)	1500.0[1]	1970	7700.0[1]	7-76	5.133[1]	4.010	2.406	9.18
9. Cooper Nuclear station, Nebr. Pub. Power Dist.	184.0	1966	395.3	74	2.148	1.748	1.748	7.23
10. Rancho Seco Nuclear Unit No. 1, Sacramento	142.5	1967	347.0	74	2.435	2.026	1.239	3.11
11. Dulles Airport, Wash. DC	66.0[1]	1959	108.3[1]	62	1.641[1]	1.641[2]	1.486	14.10
12. Second Chessepeake Bay Bridge	96.6[1]	1968	120.1[1]	6-73	1.243[1]	1.104	1.104	2.00
13. Arkansas Frying Pan Project, Ruedi Dam	12.8[1]	1962	22.9	72	1.789[1]	1.636	1.145	1.36
14. Ark. Fry. Pan. (Sugar Loaf)	6.1[1]	1962[1]	10.2	73	1.672[1]	1.500	1.500	3.75
15. Ark. Fry. Pan (Boustead Tunl)	9.2[1]	1962	21.2[1]	73	2.304[1]	2.078	1.233	1.92
16. Rayburn Ofc. Bldg. Wash. DC	64.0[1]	1956	98.0[1]	6-66	1.531[1]	1.531[2]	1.342	2.99
Weighted Average					2.539	1.945	1.548	4.09

[1] Does not include interest.

[2] Observed inflation was less than anticipated.

Editorial Note: Professor Mead's initial cost estimate for the Alyeska Pipeline is an early estimate and is not discussed elsewhere in this report.

"Second, the initial cost estimates must be corrected for changes in the scope of the project. For example, the initial capital cost estimate for the Rancho Seco Nuclear Power Unit #1 constructed by Sacramento Municipal Utility District was based on a capacity of 800 megawatts. Capacity was increased during the construction process to 912 megawatts. The cost of changes in project scope have been estimated and added to the initial cost estimate.

"Table 2 shows the initial unadjusted ratio of observed to "final" cost in Column 6. This cost overrun estimate has been adjusted for each of our two factors in Columns 7 and 8. On an unadjusted basis, the Alyeska pipeline appears to cost 5.1 times the initial estimate. The adjusted ratio shows that in the case of Alyeska pipeline, the final cost estimated on August 1976 will be 2.4 times the initial cost estimate...

"On an unadjusted basis, the weighted average of all sixteen 'completed' costs was 2.54 times the initial estimated capital cost. After adjustment for two 'excused' factors, the final cost was still 1.55 times the expected cost...

"The nuclear plants, with their high rates of technological uncertainty, have a relatively high adjusted cost overrun rate.... The proposed natural gas pipelines are similar to the nuclear plant construction cost estimation problem in that there is a high rate of uncertainty. In the case of nuclear plants, the uncertainty is due to a new technology. In the case of gas pipelines, it is due to a new environment. While gas pipelines have been constructed under permafrost conditions, and one oil pipeline has been constructed from Prudhoe Bay to southern Alaska, there has never been a case of either a 42 inch or of a 48 inch high pressure pipeline constructed over great distances within the Arctic Circle.

"There is another similarity between the nuclear power plants and the proposed gas pipelines. Both involve 'cost-of-service' tariff arrangements and are therefore effectively 'cost-plus' contracts. As such, the incentive to minimize actual construction costs is relatively weak.

"There is also a point of dissimilarity between the nuclear plants and the natural gas pipeline situation. In the nuclear cases, it is not obvious that several applicants were competing for the same permit. Rather, a single utility or a consortium of utilities normally proposes a project and seeks regulatory approval. In the gas pipeline case, three applicants are competing where the rule of the game is clear -- the least cost estimate wins the major advantage.

"Of the sixteen projects considered in Table 2 , probably the Alyeska pipeline comes closest to the natural gas pipeline situation. The environmental similarity is obvious. Two points of dissimilarity, however, are also present and important. First, cost underestimation in the Alyeska case did not occur because of multiple applicants each attempting to show least cost. Second, an economic incentive existed in the Alyeska case to keep costs under control. This conclusion follows from the fact that the 'net back' of revenues to the oil companies will be reduced by any and all cost overruns...

"If tariffs governing the transportation of gas through an Alaskan pipeline are governed by a 'cost-of-service' provision, then this 'cost-plus' feature must be expected to generate overruns at least as great as those of Trans-Alaska oil pipeline...

"This analysis of the cost overrun record of sixteen large projects has not, and cannot, indicate the probable overrun on any Alaskan natural gas project. At best, the analysis merely suggests the extent of the problem to be anticipated. The analysis serves as a warning for gas consumers and for regulatory authorities. The extent of the cost overrun will probably be determined by the incentive system which guides management in the construction phase. If an 'all-events, cost-of-service' tariff is granted, then the project clearly becomes a cost-plus contract and the incentive to economize on construction costs is simply not present. This leaves natural gas consumers extremely vulnerable."

D. Relation to Other Issues

A realistic assessment of the possibility and impact of construction delays and cost overruns is of interest in itself, but it is the interaction with other major elements of the decision process that gives it great importance. A few of the important implications of construction delay and cost overrun follow.

The substantial potential for schedule delay and cost overrun for each of the projects under consideration is a major factor in the difficulties encountered in attempting to privately finance these projects. While this is formally recognized in Chapter 12 of the Commission's Recommendation concerning financing for the projects, the magnitude of the problem has not been addressed in detail. That the financial ramifications of schedule delays and cost overruns deserve much greater attention and that such attention will be forthcoming in the final financial arrangements for the chosen system is not in doubt. An important observation is that, to the extent private investors are risk averse, the project with the least amount of economic uncertainty will enjoy advantages in private financing.

Should the government become involved in financing or financing guarantees, the potential for schedule delay and cost overrun becomes a more serious factor in the President's decision in at least two ways. First, the faith and credit of the government, or even a rather large amount of the taxpayer's money, would become involved and the government should have every incentive to scrutinize its expenditure. Second, the project begins to take on the characteristics of a government-sponsored cost plus fee contract which does not have any strong protection against overruns and which, historically, appears to be overrun and delay prone. Simultaneously the government's exposure and the potential for overruns and delays increase if some sort of incentive structure is not implemented.

The conservation interveners have raised the point that one implication of schedule delay and cost overrun is the pressure created on project management to be less than fully committed to regulations and stipulations protecting the environment. They argue that this would be particularly evident in a situation of "schedule crashing" where, for political or economic reasons, a project was dedicated to meeting a completion schedule "at all cost". While theoretically it is possible for monitoring government agencies to prevent degradation of the environment under any circumstances, experience to date indicates that it is very difficult in the field to make the correct judgments every time. Further one can imagine a scenario in which the Federal Government has a financial position in the project and to that extent is motivated along with project management to minimize cost overruns and insure completion on schedule.

Certain issues have, for each of the projects under consideration, both design and safety implications as well as economic implications. Good examples are pipeline integrity and LNG safety design and operation. The analysis in this report addresses only the economic implications.

Two of the most important criteria for comparing the three projects are the net national economic benefits and the cost of service that will result from the construction and operation of each project. Examination of the record clearly indicates that, to the extent the engineering estimates of schedules and cost do not represent the expected values that will actually occur, both the calculation of net national economic benefits and cost of service for each of the projects are seriously biased. This potentially very serious distortion in two of the most important criteria is deemed by the FPC not likely "to be a controlling factor" although no justification or analysis is given for this judgment. Most analysts (and most investors) would argue that the more useful estimates of net national economic benefits and cost of service would be those explicitly including the best estimates of anticipated schedule delay and cost overrun.

Institutional considerations, such as approvals, permits and Federal, State, and local oversight functions have substantial potential for inducing both schedule delays and cost overruns. To some degree this has occurred in the oversight of the Alyeska construction and at the present time the oversight process represents a substantial uncertainty in the economics of a natural gas transportation system. The Canadian decision process also has potential for introducing delays. These delays can lead to time lags in delivery of natural gas to the lower 48 states and thus result in economic loss.

E. Inflation Adjustments

The estimated capital costs (in 1975 dollars) of **all** three projects were obtained from pages VIII-2 and VIII-3 of the FPC Recommendation to the President. The El Paso construction costs (1975 dollars) presented in Table 3 are based upon the total estimated construction cost for the El Paso facilities in Alaska as stated in footnote 9 of page VIII-3; these estimates represent the construction cost of the facilities before the anticipated revenues earned during the testing and start-up period are subtracted. El Paso has proposed, but is not required, to give customers the advantage of a lower rate based on a reduction of capital costs by revenues gained previous to commission.

The conversion of the estimated capital costs of all three projects from 1975 dollars to first quarter 1977 dollars was based upon the best available indicators contained in the Monthly Labor Review, Construction Review, and worksheets of the National Income Division of the Bureau of Economic Analysis. In some cases, specific information for the rate of change of prices in Alaska was available, while in other cases the available data was on a national level. As a result, these calculations of the cost increases due to inflation should be considered rough estimates. Also, no attempt was made to determine the relevant rates of change in Canadian prices during this period, but rather U.S. price changes were assumed to apply to both the

Canadian and U.S. portions of the routes. This assumption is reasonable, as any differences between the rates of change of prices in comparable sectors of the two economies probably disappear, once an attempt is made to allow for the changing relative value of the two currencies.

TABLE 3

INFLATION ADJUSTMENTS
(1975-1977 Dollars)

Project	EXCLUDING AFUDC		INCLUDING AFUDC	
	Millions of 1975 Dollars	Millions of 1st Qtr 1977 Dollars	Millions of 1975 Dollars	Millions of 1st Qtr 1977 Dollars
Alcan	5,781	6,441	6,761	7,533
Arctic Gas	5,621[a]	6,222[a]	6,729[a]	7,448[a]
	6,783[b]	7,509[b]	8,147[b]	9,019[b]
El Paso	6,114[c]	6,867[c]	7,079[c]	7,972[c]
	5,588[d]	6,276[d]	6,571[d]	7,381[d]

a These costs are 100 percent of the facilities carrying only U. S. gas, and 75.33 percent of the facilities carrying both U. S. and Canadian gas.
b These are the total costs of the Arctic project.
c These are the total capital costs of the El Paso project.
d These are the capitalized costs, with revenues gained previous to commission subtracted, which El Paso plans to use in determining its rates.

Sources: The estimated capital costs (in 1975 dollars) of all three projects, both including and excluding AFUDC, were obtained from the FPC Recommendation to the President, pages VIII-2 and VIII-3. These cost estimates were inflated to 1977 dollars by means of a weighted average of the relevant price indices (using major cost breakdowns for each system) presented in the Monthly Labor Review, Construction Review, and worksheets of the National Income Division of the Bureau of Economic Analysis.

II. PRINCIPAL CONSTRUCTION UNCERTAINTIES

Each applicant has presented a project construction plan describing his proposed construction activities, and the associated cost estimates and schedule for their accomplishment. Despite the resources which have gone into preparation of the project plans, each plan is subject to some degree of risk of cost overrun and completion delay. Based on review of the applicant plans, the FPC record and Recommendation, and the several risk assessments prepared on the competing projects, a number of key construction issues have been identified which present significant potential for cost overrun or schedule delay in completing any of the plans. These issues include:

- Pipeline Construction and Productivity
- Snow Roads and Work Pads
- Pipeline Structural Integrity/Availability of U.S. Manufacturing
- Frost Heave/Thaw Settlement
- Construction Logistics and Transportation Corridors
- Labor Availability
- Seismic Design
- Liquefaction Plant
- LNG Tankers
- Project Management and Scheduling

A. Pipeline Construction and Productivity

1. Arctic Gas

a. Description. Arctic Gas proposes to construct the northernmost 300 miles of pipeline in winter months. This is intended to minimize the impact of the construction activities on the sensitive tundra vegetation. Summer construction is planned from mid-Alberta southward where the above concern does not exist.

b. Summary of Positions. The FPC *Recommendation to the President* states "on balance, the evidence warrants a conclusion that construction in the high Arctic is possible and that Arctic has presented a reasonable program for its execution". The judgment of this report is that while the Commission may be technically correct--winter construction is possible--they have seriously underestimated the economic consequences of attempting construction during the high arctic winter. Winter arctic conditions include prolonged darkness up to 18 hours per day, and average wind chill equivalents below -35° much of the time. Alyeska's winter experiences do not tend to support a conclusion that large scale construction in the high arctic winter is economically feasible.

The testimony of the Alaskan State Pipeline Coordinator before the Council on Environmental Quality lucidly presents winter coldness and darkness implications upon productivity and cites many construction activities facing great economic uncertainties. Other sources of information, including the Interior Department Report to Congress under P. L. 93-153, also emphasize how acts of nature can jeopardize construction and budget goals. Practical experience with arctic winter construction on the scale proposed by Arctic Gas simply does not exist, making it to a large degree, an "economic experiment".

2. Alcan

a. Description. Alcan proposes to construct its Alaskan and Canadian pipeline portions in the summer months, and to avoid as much as possible difficult winter construction. It proposes that, along its specific route, non-winter construction can occur satisfactorily with no more adverse tundra scarring than would be realized under winter construction. This is accomplished by judicious route selection through its short discontinuous permafrost region, and use of Alyeska Oil Pipeline haul roads and work pads. A rapid construction rate is proposed by Alcan during summer months.

b. Summary of Positions. It is generally agreed that summer construction rates will exceed winter construction rates. However, Alcan's productivity has been questioned as being achievable even during summer construction by the FPC, particularly during "peak" summer months. The major issue with this system is the specific construction rate which can actually be attained during productive summer months. The FPC has not accepted Alcan's proposed rates, but, rather, added one year to Alcan's schedule.

3. El Paso

a. Description. El Paso has planned for winter construction for all except the southern portion also to minimize construction impacts upon permafrost and tundra scarring. Reliance of El Paso upon snow roads and work pads is not the critical factor it is for Arctic Gas because existing Alyeska Oil Pipeline haul roads will be available. Only the northerly portion of the El Paso line would be in continuous permafrost and El Paso does not schedule work in December and January.

El Paso proposes summer construction only for the portion of its route in southern Alaska through the Chugach Mountains and other areas where wind and snow conditions coupled with terrain are too severe to permit winter construction. This proposal, although in difficult terrain, has not been significantly contested.

b. Summary of Positions. The same concerns for winter construction portions of the El Paso system exist as discussed under Arctic Gas, with the difference that much less pipeline is to be constructed and that an all weather haul road is available.

4. Comparative Assessment

The major pipeline issues are summer construction versus winter construction as they influence pipeline progress and the environment.

With respect to construction productivity, Arctic Gas is the most uncertain due to the planned winter construction for the northern portions. Arctic Gas has underestimated the problems caused by lack of available work time in winter due to holiday shutdown, weather difficulties, lack of daylight and absence of significant winter pipeline work experience north of the 60th parallel.

The El Paso plan for winter construction is also economically uncertain, but because of availability of Alyeska roads and work pads some advantage is gained over Arctic Gas.

Alcan's plan for summer construction makes it the least uncertain in achieving economically acceptable progress, although Alcan's estimated productivity is considered optimistic even for summer work. As with El Paso, Alcan can rely on existing roads for access and support of its program. Alcan may have to do some winter construction at increased cost in order to avoid damage to the environment by crossing rivers during the summer.

B. Snow Roads and Work Pads

1. Arctic Gas

a. Description. Arctic Gas has scheduled most of its construction work to occur during winter months, using snow roads and snow work pads, from November to April over a three-year period. The precise starting and ending dates for the winter construction period will be controlled by the number of continuous "freezing" days to allow for buildup and establishment of frost-penetration, as well as the onset of warmer temperatures resulting in the surface thawing of the tundra and permafrost. It was also stated that Arctic Gas construction crews will operate above the 65th parallel on roads and work pads constructed of compacted snow.

b. Summary of Positions. The FPC conclusion is that the Arctic Gas proposal to use snow roads and snow work pads for winter construction is "feasible." However, several construction uncertainties were identified. Heretofore, the most recent technological experience has been with arctic roads designated variously as ice roads or winter trails. These types of roads are generally used for the movement of light loads. Arctic Gas performed three snow road construction and use tests, with the last test reported to have demonstrated the technical feasibility of compacting snow. Unfortunately, such small scale tests do little to demonstrate the economic feasibility of large scale field operations that must rely on the construction and maintenance of snow roads.

Arctic Gas proposes to use snow fences to accumulate the volume of snow needed for construction of the snow roads and pads, but the North Slope is a light-precipitation region and adequate snowfall does not always occur. In that event, Arctic Gas proposes to manufacture snow by use of a "super-snowmaker," based on ski resort technology, on a scale which has not been designed or tested.

Questions were raised on the water supply source for snowmaking. In certain areas, springs exist, but water withdrawal has to be carefully controlled to prevent harming fishlife and their spawning habits. On the North Slope, there are numerous rather shallow (six feet or less) lakes; these lakes generally freeze solid--top to bottom--which precludes the existence of fishlife. Arctic Gas has proposed "mining" these lakes for their ice which could be crushed and used like gravel, and deepening the lakes to provide a water reservoir (or sump) below the six-foot layer of ice.

El Paso, Alcan, and State of Alaska have all attacked Arctic's proposed use of snow roads and pads. Their principal criticisms centered on opening dates for snow road construction and the impact on Arctic's construction schedules (delays) with added costs, unpredictability of snowfall, water availability, damage to tundra, etc. Major basis of these objections stem from unsuccessful snow roads, and the problems involved in providing enough water on the North Slope.

2. Alcan

a. Description. Alcan construction in Alaska is projected from April to the end of September--thus precluding any requirements for snow. In Canada, however, some winter construction by Alcan is planned. Alcan would, however, encounter the same need for gravel in Alaska as El Paso (see below).

b. Summary of Positions. There are no forseeable problems with regard to Alcan's requirements for snow.

3. El Paso

a. Description. El Paso will have the benefit of the Alyeska haul road and Richardson Highway and will use snow only for work pads.

b. Summary of Positions. El Paso intends to use extensive amounts of gravel for the maintenance of existing haul and lateral roads. Arctic Gas argues that El Paso has a gravel shortage, asserting that gravel supply must be considered regionally, and further that for the 200 miles from the Brooks Range to Prudhoe Bay, gravel is in short supply. In the final analysis, it was judged that the total available supply of gravel along the pipeline corridor appears to meet El Paso's requirements--with recognition that there are localized and even regional gravel shortages. It is also recognized that El Paso's use of snow work pads would reduce its requirements for gravel. It is felt that additional studies on gravel supply are needed.

4. Comparative Assessment

Arctic has proposed to make extensive use of snow roads and snow work pads. El Paso intends to use only snow pads. Alcan has scheduled their construction to occur primarily from April to the end of September--thus precluding any major requirements for snow.

Three significant questions have been identified with regard to the use and construction of snow roads and snow work pads. The first is the economic uncertainty associated with the construction and durability of snow roads and pads for moving the heavy and continuous loads anticipated during the winter construction periods. The second question concerns the availability of snow on the North Slope in economic quantities for construction purposes. A light snow cover may preclude gathering or harvesting techniques by surface scraping. The economic effectiveness of passive snow collecting systems such as snow fences is still uncertain. The third question is the economic feasibility of collecting water on the North Slope during winter months and manufacturing snow from it. While many lakes freeze solid precluding them as a source for water, it has been proposed to crush the ice and use it as a gravel substitute.

Due to the lack of any large scale experience, substantial uncertainty remains concerning the economic use of snow roads and snow work pads.

C. Pipeline Structural Integrity/Availability of U. S. Manufacturing

1. Arctic Gas

a. Description. Arctic Gas foresees no pipeline structural integrity or availability problems for its X-70 grade 48-inch 1680 psi pipe from Alaska to Southern Alberta. Although there is no specific DOT requirement for crack-arresters, Arctic Gas plans to use them, and is continuing its testing to determine optimal design and intervals for them.

Arctic Gas plans to procure most of its 48-inch pipe from the STELCO Company in Welland, Ontario; other suppliers include U. S. Steel of Baytown, Texas, and Mannesmann of Germany. Each of these manufacturers appears able to produce adequate quantities of pipe to meet the scheduled construction.

b. Summary of Positions. There appear to be no serious pipeline structural integrity or availability issues for Arctic Gas.

2. Alcan

a. Description. Alcan expects no workmanship or structural integrity problems with its grade X-70 48-inch 1440 psi pipe. At its pipe pressure and stress levels (lower than the Arctic or El Paso proposals), Alcan claims crack-arresters are unnecessary, and does not plan for any other than "natural arresters" such as thicker wall pipe, valves, etc.

Alcan proposes to procure its pipe for the Alaskan portion from U. S. Steel at Baytown, Texas, unless its price is not competitive with foreign pipe, in which case foreign pipe may be substituted. (Japanese pipe is currently $150/ton less than U. S. pipe.) For the Canadian portion the pipe will be produced by the IPSCO and STELCO Companies of Canada. It is claimed that the total 48-inch pipe production capability of these companies would be absorbed by the Alcan pipe, although pre-ordering would reduce the risk of manufacturing peaking problems that might jeopardize construction.

b. Summary of Positions. There appear to be no serious pipeline structural integrity or availability issues for Alcan.

3. El Paso

a. Description. El Paso expects no workmanship or structural integrity problems with its pipe. Although no official DOT crack-arrester requirements exists, El Paso plans to determine how crack-arresters should best be used through two years of experimentation with crack propagation before any pipe is laid.

El Paso proposes to procure its 42-inch 1670 psi X-65 pipe from three U. S. sources: U. S. Steel, Bethlehem Steel, and Kaiser Steel. U. S. Steel's Baytown, Texas plant would provide 400,000 tons of the total necessary 750,000 tons of pipe. That plant claims it could produce the total amount if Bethlehem and Kaiser (which lack proven experience) are unable to provide their shares.

b. Summary of Positions. There appear to be no serious pipeline structural integrity or availability issues for El Paso.

4. Comparative Assessment

Although no DOT crack-arrester specifications exist, neither DOT nor any applicants foresee problems in this area. DOT's Office of Pipeline Safety Operations feels that the proposed new use of X-70 pipe for pressures as high as 1680 psi poses no problem but represents a new "state of the art".

The X-70 48-inch pipe is the critical pipe for both Arctic Gas and Alcan. Other pipe is "conventionally" available. Two of the four proposed sources for it (U. S. Steel, Baytown and Mannesmann) have at least limited prototype and/or production experience manufacturing such pipe. The other four proposed manufacturers claim to be able to follow the demonstrated ability of those who have already produced it. U. S. Steel's Baytown, Texas pipe plant expansion investment at $100 million will permit three to four miles of 48-inch pipe production per day, exceeding typical pipe laying rates. Unless there are unforeseen strikes or production problems affecting pipe raw material delivery, pipe manufacturing, or manufactured pipe delivery, and especially considering pipe pre-ordering and stockpiling opportunities, pipe availability and delivery should pose no problem to any applicant.

Alcan's plan to transmit gas through the pipe at lower pressure than Arctic Gas or El Paso, should pose fewer problems than that of the other two applicants. El Paso has fewer miles of pipeline than the other applicants and plans to use more conventional pipe albeit at high pressures.

D. Frost Heave/Thaw Settlement

1. Arctic Gas

a. Description. Arctic's discontinuous permafrost corridor of about 250 miles is the largest of such corridors of the three applicants. In this corridor, Arctic Gas proposes to minimize "frost heave" by insulating and heating under the pipe.

b. Summary of Positions. Realizing that protection against frost heave is largely a site specific matter, with many ways of dealing with localized frost heave situations (such as burying the pipe deeper, replacing backfill with non-frost susceptible material, or even elevating the pipeline) as suggested by local soil conditions, the significant issue here appears to be the extent to which Arctic Gas may rely upon unproven techniques. Being unproven, the actual feasibility of the techniques is both technically and economically uncertain.

DOT's Office of Pipeline Safety Operations agrees that overcoming pipeline design problems in discontinuous permafrost can be accomplished in one way or another, but the cost and schedule impacts may be considerable.

2. Alcan

a. Description. In its discontinuous permafrost corridor of about 180 miles, Alcan proposes to minimize gas temperature effects upon underground water action which could cause "frost heave" pipeline structural dislocations by insulating the pipeline in affected areas, or by changing the gas temperatures at appropriate compressor stations. The specific insulation Alcan has proposed requires further water repellancy and durability investigation.

b. Summary of Positions. Realizing that treatment against frost heave is largely a site-specific matter, the DOT, agrees that overcoming pipeline design problems in discontinuous permafrost can be accomplished one way or another, but the cost and schedule impacts may be considerable.

3. El Paso

a. Description. In its discontinuous permafrost corridor of about 100 miles, El Paso emphasizes that frost heave solutions cannot be generalized, but are site-specific and heavily dependent on specific soil conditions. It proposes, at individual sites, to minimize gas temperature effects upon underground water actions (and possible pipe stresses and bending) by (a) insulating the pipe or (b) burying the pipe deeper, or (c) replacing backfill with non-frost susceptible material, or (d) constructing the line above ground (as a last resort). It would also change gas temperature as desirable at appropriate compressor stations.

b. Summary of Positions. El Paso claims no problems with resisting frost heave. The DOT (for all the projects) agrees that overcoming pipeline design problems in discontinuous permafrost can be accomplished one way or another, but the cost and schedule impact may be considerable.

4. Comparative Assessment

Pipeline and building-like structure and foundation problems in areas of continuous permafrost are not thought to be significant because of much previous Arctic structure experience by U. S. and Canadian builders. In areas of discontinuous permafrost, however, a major permafrost issue is that of how well each applicant will be able to address site-specific (as a function of ground and soil conditions) design problems. While each applicant has essentially the same frost-heave-resistant techniques available to it, all of the techniques proposed by the applicants remain unproven. On the positive side, it is agreed that the discontinuous permafrost problems can be overcome one way or another even though the cost impact may be considerable.

There is also the issue of how each applicant would implement a different technique in a corrective fashion if, once the pipeline was constructed, frost heave did occur and pipeline failure resulted. The opportunity to try new techniques could be hindered by the inability of material delivery during certain seasons.

On balance, because the discontinuous permafrost problems are similar for all three applicants, the El Paso project which has a shorter discontinuous permafrost corridor would seem to be least vulnerable to pipeline frost heave problems. Arctic Gas by the same token would be the most risky.

E. Construction Logistics and Transportation Corridors

1. Arctic Gas

a. Description. Transportation of large amounts of pipe, material, construction equipment, and personnel to the work sites in a timely manner is a critical element in the ability to maintain progress and meet construction schedules. Arctic Gas relies primarily on moving this material to a transhipment point on the "Mackenzie River for barging to advance staging areas during summer navigable seasons. In addition, new barges and tugs must be moved overland to the head of the Mackenzie to augment the existing fleet for this heavy cargo burden. Transportation from staging sites to work sites is planned using snow roads constructed after each winter freeze-up. Because of this sequence, any material which is not obtained on schedule at its source may be delayed by an entire year in delivery to the work site. Furthermore, any breakdown in the barge delivery system could block delivery of all materials to the advance staging areas. Approximately 1350 miles of the Arctic Gas system in Alaska, the Yukon, and the Northwest Territories is planned to be supported by the surface transportation system described above or by ocean delivery to the North Slope.

b. Summary of Positions. FPC examined an allegation by El Paso that Arctic underestimated the need for more expensive air transportation. The FPC found that the Arctic Gas logistics plan would be "feasible", and that transportation problems would be covered by the 10 percent contingency allowance. Other independent studies (e.g., DOI, FENCO) have found significant potential for problems.

2. Alcan

a. Description. Construction logistics for Alcan will rely on existing marine, railroad, and highway transportation systems, which are essentially all weather routes. The Alcan right-of-way follows the Alaskan Highway and the Alyeska haul road closely for most of its northern segment. Rail service from ports on the Gulf of Alaska to Fairbanks will permit staging of materials at an interior point. No major impediments would be expected. There may be a problem with traffic congestion along the Alaskan Highway, but this can be minimized by delivery of most materials to summer construction sites before the summer peak of tourist travel. The Alyeska experience with highway damage may result in the stipulation of load limits or weight penalty for pipeline traffic or for a maintenance responsibility by Alcan. One feature of the logistics plan which has some risk is the delivery of 158,000 tons of pipe to Prudhoe Bay by barge prior to the first construction season. Sea ice compresses against shore at Point Barrow even when open water prevails along the rest of the route.

This sea route only opens for brief periods during the summer season. Alcan is aware of the problems this presented Alyeska, and it plans to deliver the pipe one year before construction begins. If the delivery cannot be completed as planned, there is sufficient time to return the pipe to the Gulf of Alaska for overland delivery to the North before construction is scheduled to begin.

b. Summary of Positions. No logistics problems were mentioned in the FPC review. The difficulty of using barge transportation to Prudhoe Bay is mentioned above and also in the risk assessment report prepared under contract for EPA. The additional cost which would be incurred if barge delivery does not work has been considered in Section V. The exposure to public road problems is based on DOT experience with the Alyeska project.

3. El Paso

a. Description. Similarly to Alcan, El Paso will rely on existing marine, railroad, and highway transportation systems which are essentially all weather routes. The El Paso right-of-way closely parallels the Alyeska haul road or public highways for its entire length. Rail service is also available from ports on the Gulf of Alaska to Fairbanks permitting an interior staging area. Where access to the right-of-way is by public highway, some problems may be encountered with traffic congestion, weight limits or penalties. Obligations on

El Paso may be imposed to mitigate or compensate for highway damage. The El Paso plan also relies on shipment of some 150,000 tons of pipe to Prudhoe Bay by barge exposing them to some of the problems described in the Alcan case. The difference is that El Paso's winter construction plan does not allow as much time as in the case of Alcan for diverting barges to ports in the Gulf of Alaska and transporting overland to the North Slope.

b. Summary of Positions. The FPC did not mention logistics for El Paso. The risk assessment report prepared for EPA describes ice or other interference of barge transportation to Prudhoe as moderately likely. If the problem is encountered, it is likely to not affect construction schedules but it will increase costs. These costs have been considered in the results in Section V.

4. Comparative Assessment

The logistics operations for construction projects of this magnitude, no matter how well planned, are certain to encounter problems in execution. Alyeska experience indicates that, even with an all weather road and primarily summer construction, logistical support for large scale operations in remote areas of the Arctic is very complex and expensive. Management will be faced with decisions between accepting the attendant cost of delay due to shortages, or incurring additional costs to expedite deliveries. They may also employ additional inventories to compensate for procurement delays. While it is not clear that any of the proposals make sufficient allowance for logistics contingencies, there are differences in the potential of each system for logistical difficulties beyond those anticipated.

For the pipeline segment, El Paso is least sensitive to logistics problems. It has a shorter construction schedule falling well within overall project completion. It is the shortest pipeline and is not remote from existing transportation systems.

The Alcan proposal ranks very close to El Paso on this question, although its greater length of Arctic pipeline construction which increases its sensitivity, is offset by less reliance on an ocean system.

The Arctic Gas proposal is significantly more vulnerable to major problems. Because of seasonal constraints on river barging and snow roads, a major logistical difficulty could delay deliveries into the next shipping season. In addition to the specific difficulties described in the discussion of this project, the general effect of Arctic Gas' greater remoteness from community and transportation infrastructure will limit the responses to shortages. Every ameliorative measure, such as air freight when weather permits, will have significant cost impact.

F. Labor Availability

1. Arctic Gas

a. Description. The issue of labor availability has two dimensions. The first is the requirement for an adequate pool of manpower, with appropriate skills, and with wages consistent with project cost estimates. The second is harmony in labor relations permitting utilization of labor as required by construction schedules and cost estimates. Given an adequate supply of labor with general technical aptitude, specific skills can be developed with on the job training. An overly optimistic evaluation of the labor market could result in a combination of low wage level expectations and high productivity estimates. If Arctic Gas is constrained to hire Canadian workers only in Canada, it will draw from a labor pool small in comparison with the needs of this project. The Arctic Gas system has 2304 miles of its route in Canada.

b. Summary of Positions. The DOI report states that the longer the route thru Canada, the more susceptible it will be to skill shortages. The FPC did not examine labor supply but implies that Canadian labor pools are adequate. However, the FPC finding that Alcan will exceed labor availability applies to Arctic Gas as well. Approximately 7,000 pipeline craft workers will be needed during the peak years when work in the North is coupled with summer work in the South. It is not clear that labor market and training requirements have been adequately estimated.

2. Alcan

a. Description. The Alcan system is subject to the same issues described for Arctic Gas with the difference that the Alcan system has 2022 miles of its route in Canada.

b. Summary of Positions. FPC forecasts that the Alcan labor requirements will exceed the available work force, particularly in Canada. In their view, this will result in hiring marginally qualified workers thus Alcan may be unable to achieve the productivity which is already judged optimistic.

3. El Paso

a. Description. El Paso is subject to the same general issue of labor availability, but less the issues regarding the Canadian labor market. The pipeline distance is approximately equal to the recently completed Alyeska oil pipeline. There is some relief in the labor supply appropriate for El Paso since more diverse skills are required resulting in less concentration in a few crafts.

b. Summary of Position. Despite indications of more rigid labor conditions than existed for Alyeska, the El Paso project is judged to have the least labor uncertainties. Existing infrastructure along the El Paso route should serve to mitigate boom effects during the work.

4. Comparative Assessment

There is no in-depth analysis of labor markets for the proposed projects, however, those references in the record to labor availability give the impression that it is not a significant problem. In view of the potential impact of labor on cost and schedules, the issue should be explicitly considered. It would appear that both Arctic Gas and Alcan have a high vulnerability to labor shortages. El Paso would be affected to a much lesser extent than either of the others. Beyond the problem of labor availability are strikes, safety provisions, jurisdictional disputes, and wages, all of which can be minimized by a project labor agreement.

The Alyeska labor agreement provides a clear precedent for the El Paso and Alcan projects, however the massive winter undertaking proposed by El Paso and Arctic Gas are likely to create labor conditions which both raise cost and lower productivity. There are additional problems which could result from the combining of U.S. and Canadian work forces.

G. Seismic Design

1. Arctic Gas

a. Description. The Arctic Gas system routing avoids active seismic areas except for a section in Mackenzie Delta area and can be considered to be only minimally exposed.

b. Summary of Positions. The Arctic Gas system is essentially risk free provided the Mackenzie Delta area is recognized as active and appropriate seismic design and construction standards are employed.

2. Alcan

a. Description. The Alcan system approaches active seismic zones in the central Alaska portion of its pipeline route only and is considered a low risk system.

b. Summary of Positions. With so small a portion of its overall length in seismic area, the necessary precautions for seismic considerations will have negligible impact on cost and schedules.

3. El Paso

a. Description. El Paso has proposed to construct and operate a natural gas liquefaction facility at Point Gravina. Further El Paso has proposed to construct and operate an LNG receiving terminal and regasification and distribution facility at Point Conception. Both plant sites, in Alaska and California, are located in seismically active zones, which raises questions as to the feasibility of these sites for the processing of a potentially dangerous product. The pipeline must cross several seismically active areas to reach terminal facilities at Point Gravina, in addition.

El Paso concedes that it does not yet have a design specifically incorporating seismic criteria for either the pipeline or the LNG facilities, but maintains that it will be done and the time and money has been allowed for the schedule of design and the estimate of cost.

The direct motion resulting from an earthquake does not represent the only possible hazard to El Paso facilities. Consequential damage due to wave action exist as well. These are referred to as either a tsunami or a seiche. There is presence of both of these phenomena in the south Alaska coast area. It has been estimated that the maximum expected tsunami runup (height reached on land) would be 34 feet, with waves of 20-30 feet. Other sources, however, contend that greater impacts are possible.

b. Summary of Positions. The El Paso system has substantial elements in active seismic zones for the lower pipeline, the LNG plant and the regasification plant in California. These features are acknowledged by the applicant and add the burden of developing acceptable design for safety and environmental protection.

4. <u>Comparable Assessment</u>

The pipeline routes proposed by Arctic Gas and Alcan are located in less seismically active zones. Precautions in design will be required by Arctic Gas in the Mackenzie Delta and by Alcan where its route nears the active Alaska faults.

It has been generally conceded by El Paso that their investigations concerning the geologic state of their facilities sites has been rather cursory. Based upon recent seismic occurrences in southern Alaska, and the current forecasts for expected seismic activity in southern California, it would appear necessary that thorough investigations of the sub-strata in the vicinities of El Paso's proposed facilities be performed. Due to the expected delays in award of any one of the three applications being selected, and three to five years to construct the pipelines, it is felt that the requirement for satisfactory site investigation would not delay the installation of El Paso's facilities. Increases in El Paso's construction cost estimates are judged quite likely.

H. Liquefaction Plant

1. Arctic Gas

Not applicable.

2. Alcan

Not applicable.

3. El Paso

a. Description. Construction of the gas liquefaction plant at Point Gravina, Alaska represents one of the most critical activities in El Paso's proposed project. For a gas flow of 2.4 BCFD from Prudhoe Bay, the plant would contain six identical processing trains plus related support equipment which liquefy the gas. The proposed design is optimized to minimize fuel consumption and thereby shrinkage of the delivered gas.

b. Summary of Positions. The design process is relatively complex and similar to existing liquefaction plants, but the size of each train exceeds the largest existing train by a factor of greater than 2. The minimization of fuel consumption introduces sophisticated features not previously tried in this process. While it has been shown that the required equipment is available, the claimed system efficiency must yet be proven. The design is thus an advance in the technology of liquefaction with related uncertainties relative to completion of the design and procurement of the equipment within the estimated costs and schedules.

An independent evaluation by DOI indicated that El Paso's manpower estimate is probably low and that approximately 25 percent more personnel would be required. This places the cost estimate for El Paso's labor in the realm of uncertainty with potential cost schedule effects.

4. Comparable Assessment

The risks of potential delays and cost overruns due to design problems, procurement delays, site preparation problems, additional labor requirements, and start-up problems for the El Paso liquefaction plant are considered relatively high. The liquefaction plant is on the El Paso proposal's critical path; any delay results in postponed deliveries.

I. LNG Tankers

1. Arctic Gas - not applicable

2. Alcan - not applicable

3. El Paso

a. Description. El Paso has proposed to transport the liquefied gas produced at the liquefaction plant at Point Gravina, Alaska by means of tankers. For a flow of 2.4 BCFD of gas from Prudhoe Bay, El Paso has estimated that eight tankers of 165,000 cubic meter capacity with an average speed of 18.5 knots would be required to deliver the LNG equivalent of 2.1 BCFD to Point Conception, California. The capacity of each of these tankers exceeds the size of any existing LNG tankers by approximately 25 percent. The size of these tankers would be approximately 1000 feet length by 150 feet width by 100 feet height with drafts of 35 to 40 feet.

b. Summary of Position. It has been concluded that the eight tank fleet is sufficient to transport the planned quantity of gas from Point Gravina, Alaska to Point Conception, California. Should one or both terminals be relocated El Paso says they intend to use 175,000 cubic meter tankers, thus further exceeding our previous experience. There are seven U.S. shipyards with berth dimensions to accommodate the construction of these size ships. The schedule allows the construction of the required eight ships by three of these shipyards and no particular scheduling problems are foreseen.

4. Comparative Assessment

Although the foregoing discussion indicates that no specific design construction, or scheduling problems are foreseen, the unprecedented size of these ships places their cost in the realm of uncertainty. While the economic risk is not equivalent to the risk expected from an advance in technology, the scaling up in size creates potential increases in costs of manufacture that must be considered.

J. Project Management and Scheduling

1. Arctic Gas

a. Description. The issue here is the overall manageability of the construction program. Working at capacity in a remote area under Arctic winter conditions will hamper Arctic Gas capability and efficiency in responding to unanticipated problems. Shifting or adding resources will require substantial lead times under these conditions.

b. Summary of Positions. FPC did not specifically address project management, but they concluded that Arctic Gas had presented a reasonable program for executing a feasible project. In the process, they evaluated contrary evidence submitted by El Paso.

FPC recognized that the Arctic Gas construction schedule may be too optimistic and found a one year delay likely. They project the impact as only 12 percent of cost. It should be noted that the schedule calls for construction along the route from Mackenzie Delta to southern Alberta during the first two winters. Construction of the leg to Prudhoe Bay is scheduled for the third winter. This phasing provides an opportunity to evaluate winter construction experience early in preparation of the last, and most difficult, year of construction.

Both the FENCO Report and the DOI Report found project management to be very difficult for the Arctic Gas proposals.

2. Alcan

a. Description. Alcan is subject to the same kind of contingency needs as described for the Arctic proposal, however; its proximity to existing roads and reliance on summer construction are critical differences for short term reactions.

b. Summary of Positions. The FPC noted that Alcan would have the advantage of knowledge acquired by the TAPS project for the segment which will parallel the oil pipelines. They expressed a reservation, however, that specific information might not be valid if the lines are separated by 200 feet or more. Alcan also parallels existing pipelines in Alberta.

The FPC found that the Alcan schedule for beginning construction is probably overly optimistic in view of the extensive preconstruction activities which remain to be done. However, they found that any delays in beginning construction would not result in undue delays in completion. A more serious question about scheduling comes from the productivity figures used for the Canadian segment. The challenge by El Paso that the figures were too high was sustained by FPC on the basis of comparable figures submitted by Arctic. On the other hand, Alcan claims that the figures are based on the only specific experience in any of the proposals, namely Canadian gas pipeline construction by one of its member companies. While this productivity may have been demonstrated, it was not for any project the size of the Alcan proposal. The issue is that although this productivity may be realized using highly trained and experienced workers, there may well be an insufficient skilled labor pool to meet the demands during peak construction.

In view of the large portion of the proposal in this category, the issue is crucial to the cost estimate. If productivity estimates prove to be inflated, Alcan will have to make trade-offs between delay, cost and using additional crews to meet the completion schedule. RPA projects a high (90%) probability of a 1 1/2 year delay and a moderately high (70%) probability of a two-year delay.

3. El Paso

a. Description. The El Paso project consists of four major subprojects which can be managed separately under only general coordination. The pipeline project schedule is not critical in the overall project schedule. The liquefaction plant schedule provides the critical path in the overall project schedule.

b. Summary of Positions. The schedule for construction was accepted by FPC despite some allegations that incomplete site evaluations will delay the beginning of construction. RPA projects a high probability of a delay over six months and a 50% probability of a one year delay.

4. Comparative Assessment

Arctic Gas will have more manageability difficulties than either of the other two projects in reacting to unforeseen problems, due primarily to the complex, interdependent construction program.

K. Summary of Assessments

The above sections discussed construction uncertainties which could lead to cost and schedule overruns. During the FPC deliberations and subsequent Federal Agency review, certain issues have been frequently discussed, e.g., feasibility of snow roads and LNG seismic design.

The purpose of this section is to provide an assessment of the relative importance of these uncertainties in causing construction cost and schedule overruns for each of the three competing applicants.

Table 4 summarizes the judgments of five individuals familiar with the systems concerning the potential for each issue to cause cost/schedule overruns; these judgments are expressed as low, medium and high potential. (In Chapter V, these uncertainties are reviewed in a similar, but slightly different, aggregation to estimate possible dollar and time overruns.) The numbers 1, 2, 3, 4 and 5 beside Arctic, Alcan and El Paso refer to each evaluation. The scoring was accomplished by each evaluator without any knowledge of the other evaluators' scores or opinions.

A review and summation of the judgment rankings leads to the conclusion that the evaluators believe the Arctic Gas system has the highest construction risk and the Alcan and El Paso systems are much less risky and similar in ranking.

TABLE 4

RELATIVE POTENTIAL FOR SCHEDULE/COST OVERRUN

	Arctic Gas					Alcan					El Paso				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
PRE-CONSTRUCTION															
Approvals, Settlements, Stipulations, etc.	H	H	H	H	H	M	M	M	M	M	L	L	M	L	M
CONSTRUCTION															
Construction and Productivity - Winter	H	H	H	H	H	M	M	M	H	M	M	M	M	H	L
Construction and Productivity - Summer	L	L	L	L	M	M	L	L	L	M	L	L	L	M	M
Snow Roads and Work Pads	H	H	H	H	H	L	L	L	M	M	M	L	M	M	M
Pipeline Integrity and Availability	L	M	L	L	L	L	L	L	L	L	L	L	L	L	L
Frost Heave/Thaw Settlement	H	H	M	M	H	H	L	H	M	M	M	L	H	L	M
Construction Logistics	H	H	H	H	H	M	L	M	M	M	L	L	M	L	L
Labor Availability	M	H	M	M	M	M	H	M	M	M	L	M	M	M	M
Seismic Design	L	L	L	L	M	L	M	L	L	M	H	H	H	H	M
LNG Liquefaction Plant	-	-	-	-	-	-	-	-	-	-	M	H	L	H	M
LNG Tankers	-	-	-	-	-	-	-	-	-	-	L	M	L	H	M
Project Management, Scheduling, Monitoring	H	M	M	H	H	H	M	M	M	H	M	M	M	M	M

1-5 These estimates represent the judgments of five individuals familiar with the Applicants' proposals.
H - High M - Medium L - Low

III. INSTITUTIONAL AND OTHER UNCERTAINTIES

Following the selection of a gas transportation system, a number of institutional issues will remin. Resolution of these issues will require a joint effort by the successful applicant, various federal agencies, the State of Alaska, and possibly the Canadian government. If these issues cannot be resolved in a timely fashion during the initial part of the preconstruction period, delays in initiating construction and consequently in gas deliveries will likely result. In particular, four issues stand out as especially critical insofar as individual schedules and costs are concerned:

- Canadian Native Claims
- Alyeska Right of Way
- LNG Regasification Plant Siting
- Federal/State Stipulations and Permits
- Provisions of Law Relative to Schedule Delay & Lost Overrun.
- Uncertainties Associated with Alternatives
- U.S. Canadian Coordination

Each of these is discussed below.

A. Canadian Native Claims

At the same time the U. S. has been conducting its investigations and analyses, the Canadian government has been reviewing the applications for the projects that would cross Canada. The major inquires include hearings and investigations by: (1) the NEB pertinent to the certification of pipeline projects; and (2) the Department of Indian Affairs and Northern Development pertinent to the socio-economic and environmental impact of pipeline construction in the Yukon and Northwest Territories. To date, the only recommendation that has resulted from these inquiries is the report of Judge Thomas Berger on the socio-economic and environmental impact of pipeline construction in the Northern Yukon and down the Mackenzie Valley in the Northwest Territories. This report, which concerns the Arctic Gas project and the Maple Leaf project, recommended that no pipeline be constructed across the Northern Yukon, and that at least 10 years should be allowed for settlement of Native Claims issues and for development of new social infrastructure before a pipeline were built through the Mackenzie Valley. In short, the report recommends that the northernmost segment of the Arctic Gas project not ever be constructed for socio-economic and environmental reasons. This recommendation is not binding on the Canadian government and the NEB may arrive at a different finding subject to the approval of the Canadian Cabinet and Parliament. Furthermore, a similar socio-economic and environmental impact inquiry is currently underway concerning the construction of the Alcan project in the southern Yukon. The findings of this inquiry are not yet available.

It seems apparent, however, that after selecting a specific trans-Canada system, the Canadian government will be faced with the need to reach some sort of settlement of Native land claims in either the northern Yukon and Northwest Territories (Arctic Gas) or the southern Yukon (Alcan). If the U.S. and Canada select Arctic Gas, despite the Berger recommendation, a significant probability exists that the resolution of the Native claims will delay the initiation of construction on the Arctic Gas route.

It does not seem reasonable to assume that the U.S. and Canadian governments would dictate a pipeline route and simultaneously ignore the Native land claims. Nor does it seem likely that the Canadian Indians would agree to a pipeline ROW prior to reaching an acceptable settlement. Moreover, project financing will almost certainly be infeasible until a Native settlement is reached. Thus, because negotiating a settlement in the northern Yukon and Northwest Territories can be expected to require a minimum of two years and perhaps as long as four or five, there is a high probability that Arctic Gas would experience a one to three year delay in initiating construction.

impact inquiry is currently underway concerning the construction of the Alcan project in the southern Yukon. The findings of this inquiry are uncertain at this time.

It seems apparent, however, that after selecting a specific trans-Canada system, the Canadian government will be faced with the need to reach some sort of settlement of Native land claims in either the northern Yukon and Northwest Territories (Arctic Gas) or the southern Yukon (Alcan). If Canada selects Arctic Gas, despite the Berger recommendation, a significant probability exists that the resolution of the Native claims will delay the initiation of construction on the Arctic Gas route.

Recent reports indicate the Canadian Parliament will debate the pipeline in special session this summer; and that government appears to feel that it can by law designate a route which will not be subject to appeal.

Yet does not seem reasonable to assume that the Canadian government would dictate a pipeline route and completely ignore the Native land claims. Nor does it seem likely that the Canadian Indians would agree to a pipeline ROW prior to reaching an acceptable settlement. Moreover, project financing will almost certainly be infeasible until a Native settlement is reached.

Thus, because negotiating a settlement in the northern Yukon and Northwest Territories can be expected to require a minimum of two years and perhaps as long as four or five, there is a high probability that Arctic Gas will experience a one to three year delay in initiating construction.

Similarly, if Alcan is selected, it is highly probable that negotiating a settlement with Natives in the southern Yukon will delay the beginning of construction by at least six months and perhaps by two to three years. Recent public statements by Native leaders would indicate that the Indians will use the pipeline as leverage to achieve a favorable settlement. For example, in recent testimony before the Council on Environmental Quality, Daniel Johnson, Chairman of the Council of Yukon Indians, stated, "We are opposed to the Arctic Gas route forever and the Alcan route until after our land claims have been implemented to a reasonable degree. We estimate that this will take from seven to ten years from now. Only then will we consider the Alcan route or any other route through the southern Yukon.... We shall make the fullest use of the courts to gain every moment of delay we can." The debate over this issue could affect the schedule for final ROW selection and approval, and for obtaining project financing.

B. Alyeska Right-of-Way

Both Alcan and El Paso have submitted applications with route alignments using the Alyeska Right-of -Way to the maximum degree possible. ElPaso has also filed an application (its original and preferred route) which would not use the Alyeska Right-of-Way or work pad.

Both plans to construct along the Alyeska ROW have been the subject of extensive debate during the FPC hearings. The State of Alaska has indicated that it would strongly object to any alignment which did not make maximum use of the Alyeska workpad. On the other hand, both Alyeska and the FPC have indicated that a gas pipeline should not be constructed in close proximity to the oil pipeline.

Essentially, the major concern is that construction activities might damage the Alyeska oil line. In particular, the potential for equipment colliding with the above ground oil line or damage while blasting a ditch have been mentioned.

C. LNG Regasification Plant Siting

According to El Paso's schedule, the first tanker would travel from Alaska to California approximately 5 years following federal approval of the project. Allowing 44 months for construction of the terminal in California, all local and state authorizations for the regasification facility would have to be obtained within 16 months.

Preliminary engineering design would have to be initiated while legal and other requirements were being met; Western LNG has estimated that at least 8 months would be required to complete the design.

On-schedule completion of the California facility could be delayed as a result of a number of factors. First, LNG-terminal siting is an extremely controversial issue in California. Second, California has not yet decided its position on the entire pipeline question, and has recently indicated that it would favor an all-land system. The approval process is therefore likely to be lengthy at all levels, and subsequent federal-state interaction could be complex and time-consuming. The FPC has responsibility for site approval at the federal level, and numerous agencies and departments require permits at the state and local levels. Review of this process indicates a moderate probability that the site selection and permitting process will require at least 2 years (i.e., approximately 8 months more than the 16 months now scheduled). Thus, a moderate probability exists that the siting and permit process for the regasification facility would delay the entire El Paso project at least 6 months.

Pending state legislation could affect the approval process significantly. The California Coastal Act (signed in 1976) specifies that all LNG facilities should be constructed at one location, and that the site selected should be as remote as possible from human population. The act delegates responsibility for approving LNG projects to the California Coastal Zone Conservation Commission. More recently (in early 1977), however, the state government supported legislation that would place LNG facilities under the aegis of the State Energy Resources Conservation and Development Commission. In addition, an LNG facility at Oxnard would be exempted from several permit requirements.

El Paso prefers the Point Conception site because the use of navigable, and protected harbor would minimize risks to public safety. However, a number of state agencies appear to favor Oxnard since it is adjacent to other industrial development.

A federal decision selecting the proposed El Paso project under the Alaska Natural Gas Transportation Act could specify a site for the regasification facility. If the state disagreed with that site long legal delays could result. If the California Coastal Act were approved at the federal level by that time, no federal permits, licenses, or certificates could be issued "under normal conditions" to preempt state authority. However, the Secretary of Commerce could override state authority "in the interest of national security" or if the activity were determined to be consistent with the purposes of the federal Coastal Zone Management Act.

Furthermore, the Alaska Natural Gas Transportation Act could be interpreted as overruling the requirement for state certification of federal authorizations. In either case, the court would be required to interpret the federal law, creating a delay of uncertain length. It is very probable that selection of Oxnard rather than Point Conception would result in the need for an additional tanker or a larger tanker additional storage, with a resulting increase in capital costs.

D. Federal/State Stipulations and Permits

The certificate ultimately granted to the successful applicant will stipulate a detailed set of technical and environmental terms and conditions. Responsibility for preparing these stipulations rests with several federal agencies. In addition, it is expected that the State of Alaska will play a major role in determining the final stipulations. In view of the controversy regarding the manner in which stipulations were developed and applied to Alyeska it is likely that a significant amount of time will be required to develop detailed stipulations for the gas transportation system.

Because the pipeline design and installation plan will be influenced by the stipulations, the pre-construction period could be extended if stipulations are not prepared in a timely manner. Considering the number of federal agencies that will be involved together with the independent views of the State of Alaska, delays in preparing stipulations are quite possible.

Similarly, many aspects of the selected gas transport system will require a selection of federal and/or state permits. Obtaining these on schedule may prove difficult given the rather limited amount of detailed project design that currently exists. For example, the El Paso LNG plant will need water discharge permits from Alaska. State officials have already indicated that the current El Paso design would not comply with their requirements.

The potential for schedule delays in this area is generally a function of the complexity of project design (not yet in final form) and the number of governmental agencies involved.

E. Provisions of Law Relevant to Schedule Delay and Cost Overrun

There are three provisions of law that could be exercised in the event of schedule delays or cost overruns. First, in the case of a serious labor work stoppage or strike, the President could, in the interest of National health and safety exercise the Taft-Hartly Act if the situation occurred in the United States; he would, of course, have no such option if the situation occurred for the Canadian segment of a joint system. It is uncertain what capability the Canadian government would have in such a situation. Second, the President could call upon the Defense Production Act to expedite manufacture and delivery of key items that were causing bottlenecks. Again, the ability to use this for the portion of a Canadian system within Canada or an equivalent possibility for the Canadian government is uncertain. Third, in the case of an LNG system that included LNG tankers, should there be a delay in the construction of some or all of such tankers, the possibility would exist to allow a waiver to the Jones Act and hence the capability to, for the period of delay, employ international tankers (if such were available) to deliver the LNG to the West Coast.

F. Uncertainties Associated with Alternatives

This report primarily addresses the possibility and impact of construction delays and cost overruns of three specific proposals for transmitting Alaskan north slope natural gas southward. However, it is appropriate to mention alternatives for bringing other forms of of natural gas-derived energy from Alaska. While these alternatives are thoroughly addressed in a Federal Energy Administration Lead Agency Report, they are briefly mentioned below for the sake of completeness. It should be recognized that no specific proposals for these alternatives have been offered, thus specific delay and cost overruns for them will not be estimated.

Natural Gas could be processed into liquid methanol in Alaska for ease of transportation from Alaska, reconverted to gas, and used for automotive, industrial, electric generation, and protein markets. Each of these uses (for which market acceptability is unknown) would represent a major change for the methanol energy infrastructure of the lower 48 states. While methanol consideration is desirable because methanol can be easily transported via pipeline or any tank vessel at room temperature conditions, its consideration is discouraged because methanol has some toxicity problems and there are energy losses in converting gas to methanol additional losses if methanol were to be reconverted back to natural gas.

Additional uncertainties with the methanol concept exist because methanol processing plants have not previously been constructed on Alaska's North Slope, or prefabricated and transported to that area. Also, the construction of a pipeline for methanol would suffer from the same uncertainties as oil and gas pipelines from the North Slope, although methanol flow would not have to be chilled as in the case of gas.

Liquid ammonia and solid urea could be processed from natural gas on Alaska's North Slope and stored for future transportation, or transported immediately to (primarily fertilizer) markets in the lower 48 states. Both ammonia and pulverized urea could be transported in pipelines or tank vessels, while urea could also be transported via any surface mode capable of transporting a solid.

Major uncertainties associated with an ammonia and urea concept are the effect upon the fertilizer market infrastructure in the lower 48 states, whether short-distance successful ammonia pipeline transportation implies such successful transportation over long distances such as those between Alaska and the United States, and the lack of proven water transportation feasibility from Alaska's North Slope.

Clearly, conversion of Alaskan North Slope gas to methanol ammonia or urea as a way of using gas-based energy and transporting these commodities to the lower 48 states suffers from major market, technical, and economic uncertainties.

G. U. S. - Canadian Coordination

At least three major issues involving U. S. -Canadian coordination are evident at the present time. First, the financing of any project transiting Canada and carrying Alaskan gas to the lower 48 could involve detailed financial arrangements between the U.S. and Canadian governments. For example, should government funding of cost overruns be required, some arrangement in detail between the U.S. government and the Canadian government as to the sharing of the cost overrun would likely be required.

Second, given the potential for additional discoveries of natural gas in Alaska, the United States government should certainly want to know the conditions under which a unilateral expansion of a joint U.S. - Canadian system could be undertaken. To the extent that provisions for expanding a joint U. S. -Canadian system are not settled or understood at the present time, there perforce exists substantial uncertainty as to the economics of such an expansion.

The third area of uncertainty regarding U. S. -Canadian coordination is that of monitoring the construction process. For at least two reasons, the United States would ideally like to participate in monitoring the Canadian section of a joint transportation system. One is that we would like to be assured of the technical quality of the system to prevent possible flow interruptions due to faulty design or construction. And two, since most or all of the construction costs of a joint Canadian-American system will go into the cost of service to American consumers, the U. S. Government would certainly like to be in a credible position to assure American gas consumers that only justified Canadian costs have been included in the cost of service. The verification of Alyeska construction costs is currently receiving much attention by government agencies, for example. While the technical and economic desirability of a joint U. S. -Canadian construction monitoring effort would seem to exist, a cursory consideration of the problems involved in establishing such an effort would indicate that it may be a very difficult thing to accomplish. The potential for the United States to actually have any decision-making responsibility with respect to either technical or economic judgments for the Canadian portion of a transportation system is probably rather limited.

IV. PRINCIPAL OPERATING UNCERTAINTIES

The important risks during the operating phase of a gas transportation system are those that relate to interruptions of flow or service. Service interruptions could have a significant economic impact if Alaskan gas were to become a large portion of a particular system's total gas supply. Based on a review of the applicant's plans, the FPC record and recommendations, and the several risk assessments prepared previously, a number of key uncertainty issues have been identified. These issues affect the probability of occurrence plus the time and cost of return to service and include the following:

- Accessibility for Repairs
- Seismic Activity
- Failures and Accidents
- Marine Traffic Scheduling

A. Accessibility for Repairs

1. Artic Gas

a. Description. Pipe failures that would require cutting out and replacing would be the critical case. All of the replacement pipe, excavating and welding equipment would have to be transported to the scene from the storage point. During the winter season, work shelters and support facilities would also be needed. The portion of the Arctic line in the high arctic is remote from support areas and lacks conventional surface transportation. It also occupies the fragile tundra, the protection of which of which requires snow roads and work pads during construction. Comparable protective measures will also be required for emergency repair. Preparations for deploying repair crews and equipment would be a significant operating cost element. Failures at pump stations create a lesser magnitude repair problem since they are above ground; however, similar accessibility problems would exist.

b. Summary of Positions. The FPC found that Arctic Gas would have serious problems in rapidly restoring service because of its relative inaccessability and restrictions on tundra entry during nonwinter periods. With some specific exceptions, Arctic claims to be able to respond to outages by using helicopters and surface vehicles having low ground pressure footprints. The exceptions involve underwater crossings during spring and autumn transitions where access may be impossible for up to six weeks. Arctic plans two redundant parallel pipes to compensate for the exceptional case. The record does not address the issue of accessibility during the winter season.

2. Alcan

a. Description. The preceding description of the Arctic Gas proposal showed that preparations to replace damaged pipe can be a significant element of operating cost which is greater in the Arctic than for the conventional case. Access to the pipeline by surface transportation is a principal determinant of the magnitude of this cost. The Alcan route closely follows all weather highways or the Alyeska haul road for practically its entire length.

b. Summary of Positions. The FPC report found that the Alcan proposal was superior on the issue of accessability.

3. El Paso

a. Description. The preceding descriptions for Arctic and Alcan described the cost of maintaining preparations to repair pipeline outages. Access by surface transportation is a principal determinant of the magnitude of this cost. The El Paso route closely follows all weather roads for its entire length.

Accessability for service restoration of the liquefaction plant, tankers, and regassifaction plant is not viewed as a particular problem. A possible problem exist, with respect to drydocking facilities for tankers on the West Coast. It was found that two available facilities on the West Coast are fully committed. An evaluation revealed that the combination LNG tanker and oil tanker fleet would generate sufficient maintenance to anticipate that existing West Coast shipyards will provide the necessary facilities.

b. Summary of Positions. The FPC report found that El Paso would have advantages comparable to Alcan because of its accessability. It, cites an exception, the risk that winter access to the route through the Chugach Mountains could be interrupted for several days at a time by weather conditions.

4. Comparative Assessment

The Arctic project would have severe problems in responding to an outage in both summer and winter. During winter, when the consequences of lost service are greater, a large variety of material needed for winter construction would have to be transported to the work site, probably by helicopter or low pressure surface vehicle. Winter weather would limit the operation of these transporters and work pads of snow, ice, or some kind of mat would be required. For an outage in summer, transportation by helicopter or surface vehicle would be more reliable than in winter and less material would be needed for the pipeline repair. The crucial issue is the preparation of a stable work site to meet environmental protection standards. If acceptable measures are feasible, they probably would add to cost and restoration time. If they are not, then restoration may be delayed until the beginning of the next winter construction season.

The Alcan project is essentially accessible from existing roads throughout the year. Some temporary road closings may occur during the transition seasons, and delays due to local environmental impace may occur. Because of its length, Alcan may require proportionately more staging sites for repair materials than El Paso would.

The El Paso project is also essentially accessible from existing roads throughout the year. Temporary closings of roads may occur and the right-of-way through the Chugach Mountains may be inaccessible temporarily due to fog or severe winter storms. There are specific areas, particularly stream crossings, where environmental concerns may dictate significant delays in the nonwinter seasons.

In the event that existing roads were disrupted along with pipeline damage, as might result from a seismic incident, Alcan and El Paso routes are closer to existing aviation support for air delivery of repair material.

In summary, it has been concluded that the Arctic Gas system has a relatively high risk of service interruptions due to accessibility problems, the Alcan system has a moderate risk, and the El Paso system has a lower risk than either of the other two systems.

B. Seismic Activity

1. Arctic Gas

a. Description. The Arctic facilities, because they will leave Alaska on a direct easterly route, and plunge into the interior of Canada, will avoid the high seismic activity zones so characteristic of southern and south central Alaska, as well as coastal California. However, seismic activity is expected in the Yukon-Northwest Territory.

b. Summary of Positions. Arctic will have to traverse certain areas in the Yukon-Northwest Territory border area where earthquakes with Richter magnitudes as great as 6.5 have occurred. Other studies indicate that the maximum expected earthquake anywhere along the pipeline route in this region could be as high as 7.0 on the Richter scale.

2. Alcan

a. Description. The proposed Alcan route transits at least two regions where earthquakes as great as Richter magnitude 8 could be experienced. These are the Denali Fault, which Alcan's route parellels but does not cross, and the Shakwab Fault in Canada.

b. Summary of Positions. The Shakwab Fault could be the source of a large quake, though Alcan argues that the fault is "most likely" not active. Alcan states that its design is adequate for a magnitude 8.5

earthquake, and that its contingency planning includes special pipe, and ditching procedures for the crossing of active faults, should such be discovered.

3. El Paso

a. Description. El Paso's proposed cryogenic delivery system is highly interdependent. Failure of any part of the system could quickly halt delivery of Prudhoe Bay gas, and a major disaster could stop delivery for several months to a year or more.

b. Summary of Positions. El Paso's facilities are subject to the intense seismic activities of south-central Alaska. The proposed pipeline crosses three major active faults (the Donnelly Dome at Mile Post (MP) 542, the Denali Fault at MP573, and the McGinnis Bay Fault). Also, the Point Gravina site for the LNG liquefaction facilities could encounter substantial seismic activity. The epicenter of the 1964 Alaska earthquake was only 50 miles from Point Gravina. The quake caused a 4-foot uplift and 30-foot horizontal movement of the site. The El Paso system supposedly is designed to withstand an earthquake of 8.5 Richter scale intensity and 0.6g ground acceleration. Their design, however, is described only in general terms. For example, estimated costs are based upon the existence of bedrock at the liquefaction site, though no adequate core samples have been taken. The depth of bedrock would increase costs to provide system integrity.

Potential seismic activities also pose the dual problems of tsunamis (gravitational sea waves produced by any large-scale, short duration disturbances of the ocean floor - principally by a shallow submarine earthquake) and seiches (free or standing-wave oscillations of the surface water in an enclosed or semi-enclosed basin). El Paso contends the facilities are designed to withstand these phenomena. Given the location of Gravina Point and its surrounding geography and geology, the magnitude of risk is far from clear, causing Judge Litt to suggest that "it would be advisable and prudent for El Paso to redesign the marine terminal when the berths are occupied (rather than unoccupied) for a 20-foot design wave."

4. Comparative Assessment

Each of the three systems is subject to potential flow interruption from a seismic event. Based on the number of faults traversed or located on and the magnitude of a potential earthquake, it is concluded that the El Paso project has a high risk of flow interruption due to earthquakes, the Alcan system has a low to moderate risk, and the Arctic system has a low risk.

With regard to pipelines, it is potentially possible, that a locally centered seismic event can cause a rupture. Automatic shutdown features incorporated in the systems provide for limitations of the amount of gas escaping. The Alcan and El Paso pipelines with all weather haul roads would allow a quicker and less environmentally damaging repair than the Arctic system with no all-weather accessibility.

The most serious event would be extensive damage to El Paso's liquefaction facility and marine terminal due to direct earth movement, fire, or explosions, or waves. If such an event occurred while a tanker was in the terminal, further damage to the shipping system and marine terminal could occur. This would require extensive repair and rebuilding of the damaged systems, requiring perhaps one to two years to re-establish operations and flow for a high magnitude event. The cost to recover would be extensive and would include non-equipment costs for such items as personal injury, property, and liability claims.

C. Failures and Accidents

1. Artic Gas

a. Description. Pipeline accidents in conventional pipelines are rarely caused by normal operation and maintenance. Impact by "third parties" accounts for almost all of them. The remoteness of Artic's pipeline make such accidents a slight risk. Accidents due to seismic activity are addressed in the previous section, and construction standards have been imposed which minimize failures due to climate or geodynamics of the area. In the event of pipeline failure, shutdown devices would limit the quantity of gas escaping. There is little risk of ignition and gas is not a pollutant. The major impact of an accident would be service interruption.

b. Summary of Position. The DOI risk analysis developed the description above. It is concluded that a relatively low risk of flow interruptions due to failures and accidents exists for the Arctic Gas system.

2. Alcan

a. Description. Following the analysis described for Arctic, the main cause of pipeline accidents would be the impact of third parties. The Alcan project would be exposed to third parties for almost its entire length. It will be near the Alyeska haul road, the Alaska

Highway, and a number of population density areas including Fairbanks. The major effect of an accident to the Alcan line would also be service interruption, but the risk of ignition would increase with third party exposure. The Alcan line is planned to operate at pressures closer to previous experience than the other proposals which may reduce overall economic uncertainty.

b. Summary of Positions. The DOI risk analysis did not consider the Alcan proposal. Other reports do not address accident potential. It is concluded that the risk of flow interruptions due to failures and accidents for the Alcan system is similar to the risk assigned to Arctic Gas.

3. El Paso

a. Description. The following discussion excludes accidents and risks affecting population centers but pertains to failures and accidents that could cause an interruption of flow.

For the pipeline portion of the project, the risk and effect of accidents would be subject to the same kind of analysis as described for the other two proposals. The El Paso pipeline follows the Alyeska haul road and public roads, and it passes near Fairbanks and smaller population centers. Its third party exposure, per mile, is smilar to the Alcan proposal. El Paso plans to operate at a 33 percent higher pressure than Alcan.

For the processing and marine transportation phases of the El Paso project, the principal risk is related to the properties of LNG. Both the liquefaction and regasification plants are equipped with elaborate fire protection systems. The large LNG storage tanks are surrounded by trenches which can contain the complete contents of each storage tank in case of a spill. It is considered unlikely that a spill and its consequences would destroy a large portion of these plants, although local damage would probably occur. The LNG tankers share the sea lanes with other shipping creating the potential of a two ship collision. The spillage of large quantities of LNG on water due to cargo penetration is considered a major hazard to the tankers. Many safety experts including the U. S. Coast Guard agree that ignition of the vapor caused by the spill is likely to occur almost immediately. The resulting fire would probably cause major damage or destroy the tanker.

The relative complexity of the liquefaction system creates a risk of flow interruptions due to mechanical failures beyond normal wear and tear. Examples would include compressor or turbine failures and failure of cryogenic hardware.

b. Summary of Positions. Because of the nature of LNG, the El Paso system is considered to have a relatively high risk of service interruptions due to both failures and accidents. Although the El Paso pipeline is shorter than Arctic's and Alcan's and less vulnerable to accidents and failures, the LNG portions of the system outweigh this advantage.

4. Comparative Assessment

The impact of operational failure and accident risk does not appear to be very significant. For the Arctic and Alcan pipeline routes, the major consequences of a failure or accident would be temporary complete interruption of service. The same result would occur for an accident to the pipeline portion of the El Paso system, but the impact on users would be delayed for a few days because of LNG in storage or transit by ship. Since the gas from these systems is a small percent of total usage, the impact of service interruptions would not be severe unless it occurred during peak winter usage. Local impacts might be severe if distribution is not diffused. Operational failures or accidents in the LNG portion of the El Paso system would result in a longer interruption of part of the gas capacity.

The principal cause of operational accidents in the pipeline systems would be third party impact. Arctic would have less exposure to this hazard than Alcan because it would be relatively more remote. The exposure of the El Paso pipeline would be similar to the Alcan, mile for mile, but its shorter length would make its total exposure less.

The principal risk in the LNG portion of the El Paso system would be potential industrial and maritime accidents, given normal prudence in regard to LNG hazards. The modular nature of the liquefaction and regasification plants plus the fleet make it unlikely that damage due to fires, explosives, or mechanical failures would cause a complete flow interruption. As an example, if one tanker is destroyed, there would be seven other tankers available.

In summary, the risk of flow interruption of the El Paso system due to failures and accidents is considered higher for the El Paso system than for either the Arctic Gas and Alcan systems.

D. Marine Traffic Scheduling

1. Arctic Gas

Not applicable.

2. Alcan

Not applicable.

3. El Paso

a. Description. For the eight-ship fleet size (the 2.4 BCDF case), El Paso proposes to receive 2.4 BCDF at Prudhoe Bay and would deliver 2.327 Bcfd to the liquefaction plant at Point Gravina. Further processing at this facility to liquefy the natural gas for delivery to the LNG carriers results in additional product losses with a total of 2.147 BCDF being delivered to the carrier fleet. The proposed revaporization facility at Point Conception, California, would sequently receive the equivalent of approximately 2.106 BCDF in LNG form. The natural gas would then be vaporized and received by the mainline pipeline systems for further domestic distribution within the lower 48 states.

The 165,000 cubic meter design capacity of each tanker must be reduced to meet loading restructions imposed by the USCG (98% capacity), and the need to retain some residual LNG in the tanks after discharge to sustain low tank temperatures for future loadings in Alaska. These requirements result in an effective cargo capacity of 161,347 cubic meters for each LNG ship. Therefore, given an annual production of

37.4 million cubic meters of LNG at Point Gravina with an effective capacity of 161,347 cubic meters per trip, results in 232 round trips per year to ship the total LNG production to California.

b. Summary of Positions. The traffic schedule is based upon two primary determinants -- i.e., the number of ship operating days per year, and round-trip voyage time (days). El Paso estimated (and FPC concurred) that a 330 day operating year was reasonable, with a final determination of 11.31 days being required for average round trip. The 11.31 average round trip coupled with a 330 day operating year yields 29.1 voyages per year per ship. For the eight ship fleet, this results in 233.4 voyages per year for the fleet. If these assumptions are correct, the eight-ship fleet is adequate to transport the 2.147 Bcfd of LNG delivered to the fleet at Point Gravina.

The foregoing analysis assumes that Point Conception, California will be the discharge port. However, if Oxnard (which is located 70 miles south of Point Conception) is selected as the port of unloading, then the number of voyages per year (for the eight ship fleet) is reduced to 226.9 due to the increased steaming distance. The required number of voyages could be achieved by El Paso by increasing the cargo capacity of each ship to 175,000 cubic meters (now favored), increasing the service speed, or by adding one ship to the presently planned eight-ship fleet, all at increased cost.

The principal factors which could prevent keeping to their proposed schedule are failures to receive the scheduled 2.147 BCFD of LNG at Point Gravina; adverse weather conditions, particularly in Prince William Sound (snow, ice, fog, high winds) preventing docking and loading operations; labor problems, facilities breakdown at the receiving terminal in southern California. The event most likely to occur will be unfavorable weather conditions which will prevent ship navigation at the service speeds indicated in the El Paso proposal. Failure to adhere to the traffic schedule will create the need for sufficient shore-side tankage at Point Gravina to store LNG until the ships can reach the receiving terminal and conversely, excess storage capacity is needed at the southern California receiving terminal in the event the pipeline distribution system receiving regasified LNG becomes inoperative and the LNG aboard ship must be discharged.

The cost overrun incurred as a result of not meeting the traffic schedule would be minimal--being confined primarily to the installation of additional LNG tank storage facilities.

Normal short-term interruption in operations should be expected during the first year of operation of these ships. These interruptions would generally be viewed as normal and would stem from operating learning experiences, new equipment break-in periods, equipment and procedure modification to improve safety and performance, etc. No extensive annual operating cost-overruns should be expected.

4. Comparative Assessment

The transport systems proposed by both Arctic and Alcan do not require the use of waterborne transportation for operations. Only the El Paso system, as discussed above, would employ LNG ships for operational purposes and it might incur moderate additional costs due to sea traffic problems.

E. Summary of Assessments

The above sections discuss operational uncertainties which could lead to operational problems and potential cost overruns. In addition, during FPC deliberation and subsequent Federal agency review, certain issues have frequently been discussed, e.g., operational accidents, marine traffic scheduling and the effects of seismic activity. Table 4 presents a tabulation of the more highly discussed questions, along with a qualitative ranking of the risks. It summarizes the opinions of five individuals familiar with the systems; those opinions are expressed as low, medium and high risk.

A review and summation of the judgment rankings leads to the conclusion that the evaluators believe that the El Paso system has the highest operational risk, and the Alcan and Arctic Gas systems are less risky, being very similar in ranking.

TABLE 4

RELATIVE POTENTIAL FOR SCHEDULE/COST OVERRUN

	Arctic Gas					Alcan					El Paso				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
OPERATIONS															
Accessibility for Repairs	H	M	H	H	H	M	M	M	M	M	L	L	M	L	L
Seismic Activity	L	L	L	L	L	L	M	L	L	M	H	H	H	H	M
Failures and Accidents	L	L	M	M	M	L	L	M	M	M	M	M	M	H	H
Marine Traffic Scheduling	-	-	-	-	-	-	-	-	-	-	L	L	L	L	L

1-5 These estimates represent the judgments of five individuals familiar with the Applicants' proposals

H - High M- Medium L - Low

V. CONCLUSIONS

A. Construction Schedule Delay and Cost Overruns

Each of the proposals presented by Arctic Gas, El Paso, and Alcan is unprecedented in terms of sheer project magnitude in the annals of civil construction. They far exceed the costs of dams, large buildings, and urban transit systems. Only the building of the entire Interstate Highway System, or perhaps one of the largest transcontinental railroads, would exceed them. The overall cost is comparable to the entire investment in all highways, rural and urban roads, and local streets for a year.

The scale of these projects will impose major strains on management capability and on markets for labor, finance, and materials. Each project involves techniques which have had little previous commercial application or which will be attempted on an unprecedented scale. The projects will be carried out over a number of years, frequently in the presence of extreme cold, sensitive environments, difficult logistics, and undeveloped infrastructure. In addition, there are potential institutional delays.

Each applicant has presented the FPC with time and cost estimates incorporating up-to-date information and current judgments and evaluations of expert construction engineers. However, these time and cost estimates apply to the future, to situations which cannot be specified at this time and which may be very different from those anticipated.

Based on all the information available at this time, this risk assessment concludes that while the FPC estimates of cost and schedule are not totally improbable, they do not represent a best estimate of expectations. They are substantially optimistic and do not reflect a realistic consideration of the many uncertainties remaining for each of the proposed systems.

Table 5 presents the finds of this risk assessment, and a summary of the conclusions for each system is presented below.

1. Arctic Gas

Increases in cost and schedule are likely to be caused by a combination of factors, including unanticipated difficulties with winter construction, use of snow roads/work pads, seasonal constraints on logistics, use of temporary camps (and their relocation) and institutional delays. For example, the ability of men to work in the severe environment of arctic winter on the Alaska North Slope under artificial lighting conditions to the extent required to meet the schedule has never been demonstrated. Alyeska experience has not been encouraging.

Coupling the winter construction difficulties with essentially unproven snow road and snow work pad construction and use (with attendant potential problems of economical snow or water availability) and logistical

TABLE 5

EXPECTED COST AND SCHEDULE OVERRUNS

	Project Cost (Millions of 1975 Dollars)		
	Arctic Gas	Alcan	El Paso
Estimated Direct Costs [1,2]	6783[5]	5781	5588
Expected Value of Cost Overrun	2506[5]	1864	1736
(% Overrun)	(37)	(32)	(31)
Expected Value of Direct Cost	9289	7645	7324
Estimated Total Costs [1,3]	8147	6761	7381
Expected Value of Cost Overrun	4317	3159	2775
(% Overrun)	(53)	(47)	(42)
Expected Value of Total Cost	12464	9920	9328

	Project Schedule (Months from Go-Ahead)		
Estimated Construction Schedule [1]	66	45/60[4]	60/70[4]
Expected Schedule Delay	20	17	15
Expected Schedule for Actual Delivery	86	72/77[4]	75/85[4]
(Delivery Assuming January 1978 Go-Ahead)	(Mar 1985)	(Jan/July 1984)	(Apr 1984/ Feb 1985)

1. FPC Recommendation to the President: Alaska Natural Gas Transportation System, May 1, 1977.
2. Does not include Allowance for Funds Used During Construction (AFUDC).
3. Includes Allowance for Funds Used During Construction (AFUDC).
4. Alcan and El Paso identify a phase-in period; See Appendix A for discussion.
5. The U. S. share of the Arctic Gas System is $5.62 billion; the expected value of Cost Overrun on the U. S. share is approximately $2 billion.

difficulties presents a formidable task for project management. The complicated and time-sensitive task of moving the temporary camps at the end of the winter construction to a new site for the next season, using snow roads and barges, adds further to the risk of the construction scheme. The pipeline follows a route which is relatively unknown geologically and may be expected to produce surprises, with their resultant impact on cost and schedule (Alyeska provides a good example of this). Further the final pipeline design for the discontinuous permafrost is expected to present additional costs and schedule impacts. Finally, the logistic problems associated with moving all materials (and men) into the northern construction areas by barge on the Mackenzie River during summer months presents another significant element of risk. Institutional problems include such items as a Canadian Treaty and Native Claims.

Because of the above factors, the expected cost of the Arctic Gas project is estimated to be 37% higher than estimated by the applicant and his expected construction schedule to be 20 months longer than his estimate.

2. Alcan

Increases in cost and schedule are likely to be caused by a combination of factors, including use of the Alyeska right-of-way and difficulty in achieving the high productivity in Canada suggested by the applicant. The use of the oil pipeline right-of-way presents such problems as the allowable proximity to the oil pipeline and crossing the oil pipeline (above or below ground). The applicant is estimating productivity rates in Canada which are approximately twice that estimated by the DOI study. If the applicant rates are not achievable with the equipment and labor used in the estimate, then major impacts on cost and schedule are anticipated. Finally, it is anticipated that many geotechnical problems will arise (similar to TAPS) as the pipeline progresses down a relatively unknown (geologically) corridor in Canada. Since the pipeline route passes through a region of seismic activity, another element of risk is added to the construction schedule and cost.

In view of the above anticipated construction problems it is judged that the applicant's pre-construction schedule will require extension beyond that currently estimated by the applicant.

Because of the above factors, the expected cost of the Alcan project is estimated to be 32% higher than estimated by the applicant and his expected construction schedule to be 17 months longer than his estimate.

3. El Paso

Increases in cost and schedule are likely to be caused by a combination of factors, including the acceptable use of the TAPS right-of-way and construction of the liquefaction plant (at Point Gravina) on a site which is relatively unknown geologically. The use of the TAPS right-of-way presents such problems as the allowable proximity to the oil pipeline and crossing the oil pipeline (above and below ground). This route has substantial exposure to potential seismic activity, further adding to the engineering and construction complexities of the project. The liquefaction plant presents significant potential for cost and schedule overrun, due primarily to the site preparation requirements and difficult design requirements. Alyeska experienced a number of problems with site preparation. In addition, design for a high degree of seismic protection (approximately 8.4 Richter) and its implication on mechanical design and hardware further increase the likelihood of cost and schedule increases. Finally, institutional problems associated with permission to construct in Alaska and California are considered likely to extend the schedule.

Primarily because of the above factors the expected cost of the El Paso system is estimated to be 31% higher than estimated by the applicant and his expected construction schedule to be 15 months longer than his estimate.

A summary of expected cost and schedule overruns is presented in Table 5.

B. Operating Flow Interruption and Cost Overrun

While construction cost uncertainties are believed to be far more significant than operating uncertainties, the latter remain a factor to be considered in choosing a transportation system (although not incorporated into the calculations of economic benefits or cost-of-service later in this Chapter). The most significant operational uncertainties are: (a) accessibility to the system to effect repair, (b) seismic activity which could cause system shutdown or slow down, (c) accidents which could cause system shutdown or slow down and (d) scheduling of the LNG tanker fleet in the El Paso system.

1. Arctic Gas

This system, primarily because of the remoteness of its most northerly portion (Alaska and Northern Canada), is anticipated to have significant accessibility problems in the event of flow interruption. For example, a pipeline failure on the North Slope or Mackenzie Delta areas requiring replacement of pipe, especially in the summer, presents a succession of problems which can be overcome only with time, money, and possible environmental degradation. On the other hand the Arctic Gas system is located in an area of lower seismic activity and due to its remote location generally, is not considered to be a likely candidate for accidental damage. Considering the elements of operational risk, indicated above, this system is judged to have a low to medium operating risk over its lifetime.

2. Alcan

This system, due to its proximity to the TAPS haul road/work pad and the Alcan highway is not anticipated to have any severe accessibility problems during its operational phase. System breakdown in the most remote regions of its route can, however, present difficult logistic and construction problems even though an all weather road is nearby.

The Alcan system route passes through an area of low to medium seismic activity and therefore is exposed to the small likelihood of a seismic event which could cause system failure.

The likelihood of accidental damage occurring along the pipeline route is considered low, again due to the remoteness of the system, although the system is less remote than the Arctic Gas system.

Considering the elements of operational risk indicated above, the system is judged to have a low to medium risk rating, similar to Arctic Gas.

3. El Paso

This system in its operational mode couples operational risk elements of pipeline, liquefaction plant, shipping, and gasification plant operations. The Alaska pipeline is not anticipated to have any severe accessibility problems. The pipeline route does traverse a region of high seismic activity and therefore is exposed to some likelihood of a seismic event which in turn could cause pipeline failure. The likelihood of accidental damage is considered low.

The liquefaction plant is also located in a region of high seismic activity and, therefore, is exposed to the likelihood of a seismic event. The applicant indicates that the plant will be designed to survive an 8.5 Richter scale earthquake. Seismic experts have indicated that the likelihood of an event of this type during the operational life of the system is relatively high. The unanswered question, of course, is how well will the plant survive and what will be the flow disruption time. Estimates of disruption time, following an 8.5 earthquake, vary from a week or two (while the pipeline is checked for damage) to several months (required because of reconstruction and checkout). Operational risks are relatively high for the liquefaction plant, primarily due to the seismic situation.

The LNG shipping fleet's exposure to prevailing marine traffic, presenting the possibility of accidental collision, is a significant consideration, especially when in and near the loading and unloading areas. The potential for severe weather and ship breakdown causing down and disruption to the operational schedule of ship traffic is considered possible.

The gasification plant is judged to be relatively free of operational risk except for the tanker traffic problem (accidental collision) and risks associated with unloading and storage of LNG.

El Paso is more likely to experience operating flow interruptions and cost overruns than either Arctic Gas or Alcan. While the Arctic Gas system and Alcan system are judged to have a low to medium operating risk, the El Paso system is judged to have a medium to high risk.

C. Economic Impact of Construction Schedule Delays and Cost Overruns

Table 6 presents the net national economic benefits and the cost of service for each system based on the expected costs and schedules determined in this risk assessment. Appendix C presents a "worst case". Specifically:

1. Arctic Gas

The expected direct cost (excluding AFUDC) in 1975 dollars of the Arctic Gas project would be $9.3 billion -- an increase of $2.5 billion over the current Arctic Gas estimate. Moreover, Arctic Gas would require 86 months to design and construct its project to the point of full delivery -- an increase of nearly two years (20 months) over its current schedule. Assuming a 5% annual inflation rate and including AFUDC, the total cost of the Arctic Gas system will be $12.5 billion. This would lead to a 20 year average cost of service of $2.15 per MMBTU for deliveries beginning in March 1985.

2. Alcan

The expected direct cost (excluding AFUDC) in 1975 dollars of the Alcan project would be $7.6 billion -- an increase of $1.9 billion over the current Alcan estimate. Moreover, Alcan would require 77 months to design and construct its project to the point of full delivery -- an increase of 17 months over its current schedule (see Appendix A for a general discussion of schedules). Assuming a 5% annual inflation rate and

TABLE 6

NET NATIONAL ECONOMIC BENEFIT AND COST OF SERVICE CALCULATIONS [1]

Federal Power Commission Analysis	Arctic Gas	Alcan	El Paso
Project Costs (Millions $)	8147	6761	6571
NNEB (Billions $)	7.122	7.652	5.798
Cost of Service ($ per MCF)[2]	1.72	1.79	2.09

Lead Agency Analysis	Arctic Gas	Alcan	El Paso
Project Costs (Millions $)	12464	9920	9328
NNEB (Billions $)	3311	4825	3908
Cost of Service ($ per MCF)[2]	2.15	2.09	2.26

1. All values in constant 1975 dollars.
2. Includes $1.00 per MCF for wellhead price of gas.

including AFUDC, the total cost of the Alcan system would be $9.9 billion. This would lead to a 20 year average cost of service of $2.09 per MMBTU for deliveries beginning in January 1984.

3. El Paso

The expected direct cost (excluding AFUDC) in 1975 dollars of the El Paso project would be $7.3 billion -- an increase of $1.7 billion over the current El Paso estimate. Moreover, El Paso would require 85 months to design and construct its project to the point of full delivery -- an increase of slightly over one year (15 months) from its current schedule. Assuming a 5% annual inflation rate and including AFUDC, the total cost of the El Paso system would be $9.3 billion. This would lead to a 20 year average cost of service of $2.26 per MMBTU for deliveries beginning in February 1985.

APPENDIX A

CONSTRUCTION SCHEDULES

The estimated construction schedules presented in Table 5 for each system have been taken directly from the applicants as documented in the FPC Recommendation to the President, May 1, 1977. The Alcan and El Paso applicants identify a schedule to initial flow and final flow while Arctic Gas only shows a schedule to full flow. Alcan assumes that it will take 15 months for the Prudhoe field to achieve full flow capability after initial start-up. The El Paso applicant requires approximately 10 months from start of initial flow to check out the liquefaction trains in the LNG plant before achieving full flow. The Arctic Gas system is expected to begin full flow operations essentially immediately, not requiring a phase in period, because flow from the Delta is assumed to have started approximately one year earlier.

The expected schedule delays for each system presented in Table 5 identify the months which are to be added to the applicants' estimated construction schedule to arrive at the expected schedule for actual delivery.

TABLE 5

EXPECTED COST AND SCHEDULE OVERRUNS

	Project Cost (Millions of 1975 Dollars)		
	Arctic Gas	Alcan	El Paso
Total Estimated Project Costs [1, 4]	6783	5781	5588
Expected Value of Cost Overrun (% Overrun)	2506 (37)	1864 (32)	1736 (31)
Expected Value of Final Cost	9300	7600	7300

	Project Schedule[3] (Months from Go-Ahead)		
Estimated Construction Schedule[1]	66	45/60	60/70
Expected Schedule Delay	20	17	15
Expected Schedule for Actual Delivery	86	72/77	75/85
(Delivery assuming January 1978 Go-Ahead)	(Mar 1985)	(Jan/July 1984)	(Apr 1984/ Feb 1985)

1. FPC Recommendation to the President: Alaska Natural Gas Transportation System, May 1, 1977.
2. Does not include Allowance for Funds Used During Construction (AFUDC).
3. Alcan and El Paso identify a phase-in period; See Appendix A for discussion.
4. The U. S. share of the Arctic Gas System is $5.62 billion.

APPENDIX B

PROBABILITY ASSESSMENTS

PIPELINE CAPITAL COSTS
INDIVIDUAL ESTIMATES OF COST UNCERTAINTY
($1,000)

System	Arctic Gas			Alcan			El Paso		
Base Cost	6783			5781			2493		
Differential	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3
Individual Inputs	(587)	1087	4190	(583)	1061	3948	(286)	452	1461
	0	1533	7433	0	1153	4472	0	412	1505
	1200	3000	6000	1000	2000	4000	200	500	800
	600	2100	6200	300	1900	3800	250	700	1500
	300	2400	6900	290	2200	4960	90	730	1700
	0	1835	3796	0	1283	3851	(390)	284	1374
	1500	3000	6000	1000	2000	4000	500	1000	2000
Average Inputs	430	2144	5814	288	1657	4147	52	583	1477

PIPELINE CONSTRUCTION SCHEDULES
INDIVIDUAL ESTIMATES OF SCHEDULE UNCERTAINTY
(Months)

WITH INSTITUTIONAL CONSIDERATIONS

System	Arctic Gas						Alcan						El Paso					
Period	Pre-Const.			Construction			Pre-Const.			Construction			Pre-Const.			Construction		
Base Time Schedule	24			40			24			31			24			33		
Differential	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3
Individual Inputs	0	0	24	0	0	36	0	0	18	0	0	30	0	0	12	0	0	24
	0	6	15	0	12	24	0	6	14	(3)	6	12	(6)	0	12	(3)	0	9
	12	18	36	12	18	30	6	12	24	6	12	24	6	12	18	6	12	18
	0	12	36	0	12	24	0	12	24	0	6	18	0	12	24	0	0	6
	0	12	24	0	12	24	0	12	24	0	6	12	0	12	24	0	6	12
	(8)	0	24	(9)	10	34	(6)	0	30	0	12	32	(5)	0	20	(2)	6	30
Average Input	1	8	27	-2	11	29	0	7	22	-1	7	21	-1	6	18	0	4	17

PIPELINE CONSTRUCTION SCHEDULES
INDIVIDUAL ESTIMATES OF SCHEDULE UNCERTAINTY
(Months)

WITHOUT INSTITUTIONAL CONSIDERATIONS

System	Arctic Gas						Alcan						El Paso					
Period	Pre-Const.			Construction			Pre-Const.			Construction			Pre-Const.			Construction		
Base Time Schedule	24			40			24			31			24			33		
Differential	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3
Individual Inputs	(6)	0	12	(6)	0	24	(6)	0	12	(6)	0	18	(6)	0	12	(6)	0	12
	(3)	0	15	0	12	24	(3)	0	14	(3)	6	12	(6)	0	12	(3)	0	6
	0	6	12	6	12	24	0	6	12	0	6	18	0	6	12	0	6	12
	0	0	12	0	12	24	0	6	18	0	6	18	0	0	12	0	0	6
	0	0	12	0	12	24	0	6	18	0	6	12	0	6	12	0	6	12
	(9)	0	24	(6)	6	36	(6)	0	30	(4)	6	24	(5)	0	20	(4)	0	20
Average Input	-3	1	15	-2	9	25	-3	3	17	-2	5	17	-3	2	13	-2	2	11

EL PASO LNG FACILITIES CAPITAL COST
INDIVIDUAL ESTIMATES OF COST UNCERTAINTY
($1,000)

	LNG Plant/Terminal			LNG Tankers			LNG Regasification Plant		
Base Cost	1591			1234			304		
Differential	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3
Individual Inputs	0	477	1034	(62)	62	617	(15)	0	122
	0	334	2195	0	259	747	0	30	100
	0	680	1700	0	350	770	0	100	250
	200	750	1500	100	250	600	0	40	90
	200	500	1400	300	500	1200	50	150	300
	200	600	1600	100	500	1000	50	100	200
	250	500	1000	100	250	750	50	100	200
Average Inputs	121	549	1490	77	310	812	12	74	180

EL PASO LNG FACILITIES CONSTRUCTION SCHEDULE
INDIVIDUAL ESTIMATES OF SCHEDULE UNCERTAINTY
(Months)

WITHOUT INSTITUTIONAL CONSIDERATIONS

System	LNG Plant/Terminal						LNG Tankers						LNG Regasification Plant					
Period	Pre-Const.			Construction			Pre-Const.			Construction			Pre-Const.			Construction		
Base Time Schedule	9			63			12			60			24			36		
Differential	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3
Individual Inputs	0	3	12	(6)	0	12	0	3	12	(12)	0	12	0	3	12	(3)	0	6
	0	3	6	0	6	12	0	3	6	0	3	6	0	3	6	0	3	6
	0	6	12	0	6	12	0	3	9	0	6	12	0	6	9	0	3	9
	0	0	6	0	6	18	0	0	6	0	6	18	0	0	6	0	0	12
	0	0	6	0	6	18	0	0	6	0	6	18	0	0	6	0	0	12
Average Input	0	2	8	-1	5	14	0	2	7	-2	4	12	0	2	8	-1	1	9

EL PASO LNG FACILITIES CONSTRUCTION SCHEDULE
INDIVIDUAL ESTIMATES OF SCHEDULE UNCERTAINTY
(Months)

WITH INSTITUTIONAL CONSIDERATIONS

System	LNG Plant/Terminal						LNG Tankers						LNG Regasification Plant					
Period	Pre-Const.			Construction			Pre-Const.			Construction			Pre-Const.			Construction		
Base Time Schedule	9			63			12			60			24			36		
Differential	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3	Δ_1	Δ_2	Δ_3
Individual Inputs	0	5	15	(6)	0	12	0	4	14	(12)	0	12	0	4	14	(3)	0	6
	0	5	10	0	9	18	0	3	6	0	6	12	0	3	6	0	6	12
	3	9	18	3	9	18	3	6	12	3	9	18	6	12	18	3	6	12
	0	6	18	0	6	18	0	6	18	0	6	18	0	6	18	0	0	12
	0	6	18	0	6	18	0	6	18	0	6	12	0	6	18	0	0	12
Average Input	1	6	16	-1	6	17	1	5	14	-2	5	14	1	6	15	0	2	11

APPENDIX C

SYSTEMS SUMMARY

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	Cost (Millions of Dollars)			Schedule Including Institutional Uncertainties (Excluding Institutional Uncertainties) 1/		
	Arctic	Alcan	El Paso	Arctic 66 months	Alcan 60 months	El Paso 70 months
1. Base Case (no AFUDC)	6783	5781	5588			
2. Expected Increase (no AFUDC)	2506	1864	1736	20(11)	17(10)	15(10)
3. Percent Increase	37%	32%	31%	30%(17%)	28%(17%)	21%(14%)
4. Expected Total (1 + 2)	9289	7645	7324	86(77)	77(70)	85(80)
5. Standard Deviation	1657	1187	650	12.4	9.6	7.8
6. Three Standard Deviations	4971	3561	1950	37.3	28.9	23.4
7. Worst Case (4 + 6)	14,260	11,206	9274	123	106	108
8. Expected Cost of Service 2/	2.15	2.09	2.26			
(Worst Case)	3.11	2.96	2.78			
9. Expected Net National Economic Benefits 2/	3311	4825	3908			
(Worst Case)	-2.185	0.700	1.814			

1/ Includes shifting the expected delays from the base used in the group assessment to that used by the FPC.
2/ Includes $1.00 per MCF wellhead price of gas and AFUDC.