UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DESIGN REVIEW, TRANS-ALASKA OIL PIPELINE, 1974-1976

By

John R. Williams

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Preface

This report summarizes activities as the Staff Geologist from July 17, 1974 to September 29, 1976 on the Technical Staff of Alaska Pipeline Office, U.S. Department of the Interior, during the construction phase of the Trans-Alaska Pipeline project. The report is designed for in-house distribution to those familiar with the project and with the geography and geology along the pipeline corridor. Principal emphasis is placed on geologic aspects of the design review work by Technical Staff, with little emphasis on the field surveillance phase of the work.

The body of the report summarizes the sequence of the work load, the principal design problems, effectiveness of the Federal Stipulations, possible improvements in design review and monitoring, and Survey involvement in future projects of this type. Appendix A is an item-by-item commentary on the Stipulations. Appendix B is a summary of some of the geotechnical problems handled by the Staff which have special bearing on work of the Geologic Division of the Survey. Appendix C is a list of action items as of February 23, 1976 to illustrate the type of problems which Alaska Pipeline Office and Alyeska have had difficulty in resolving. Some of these, naturally, have been resolved since preparation of the list. No comments are made on the work of Water Resources Division in support of the pipeline project because most of this work was handled by the Staff Hydrologist of Alaska Pipeline Office.

This report, written in November 1976, is based on information available through September 29, 1976. It describes a number of problems that were resolved prior to commissioning of the pipeline in June 1977.

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Introduction

The Trans-Alaska Pipeline System (TAPS) is being built by eight oil companies acting through a common agent, Alyeska Pipeline Service Company (Alyeska), to transport oil from Prudhoe Bay to the ice-free port of Valdez (fig. 1). Because nearly all of the route lies across Federal and State-selected lands, an Agreement and Grant of Right-of-Way was entered into by the oil companies and the Department of the Interior, acting for the Federal Government, and between the oil companies and the State of Alaska. These agreements and the appended Stipulations enumerate the conditions for entry, construction, and operation of the pipeline and for meeting environmental requirements. Designs for the pipeline have evolved over a period of seven years from a crude map showing the approximate route of a buried line to a sophisticated design that accounts for permafrost and terrain problems and allows for environmental considerations. This evolution was accomplished with considerable effort on the part of the Government in its reviews of Alyeska's plans and on the part of Alyeska and its consultants in attempting to overcome objections. Much of the Government review of the early project design was done by the Geological Survey. By the time the Agreement and Grant of Right-of-Way was being finalized in late 1973, Alyeska's design consisted of Preliminary Design drawings, Criteria and Design Bases, some Specifications, and some of the environmental documents.

Signing of the permit, as the Agreement and Grant of Right-of-Way between the Department of the Interior and Alyeska's owner companies is usually called, took place on January 23, 1974. At the same time, the Alaska Pipeline Office (APO), headed by Authorized Officer Andrew P. Rollins, Jr., was created from the former Division of Pipeline of the Bureau of Land Management. APO reports directly to the Under Secretary of Interior, is administratively under the Bureau of Land Management, and is financed by Alyeska on a cost-reimbursible basis. A third-party contractor, Mechanics Research, Inc. (MRI) of Los Angeles was engaged to assist APO in its dual responsibility for design review and construction surveillance. MRI employed Ecology and Environment, Inc. (EEI) to provide assistance in monitoring environmental aspects, and Gulf Interstate Engineering, Inc. (GIE) to provide assistance with pipeline engineering. Other firms, such as Harding-Lawson and Foundation Engineering Co. of Canada (FENCO) have served as consultants to MRI as needed. A comparable organization to APO, but without the third-party contractor, was established by the State of Alaska as the Office of the State Pipeline Coordinator (SPCO) under the Governor. This office was responsible for design review and construction monitoring on State lands. The Joint State/ Federal Fish and Wildlife Advisory Team (JFWAT) was assembled to provide advice to both the State and Federal pipeline offices. Organization charts of APO, MRI, and JFWAT are given in tables 1-3.

Within Alaska Pipeline Office, design review is accomplished by the Technical Staff, and field surveillance is handled by field engineers called Authorized Officer's Field Representatives (AOFR) working under the Construction Coordinator. Both groups report to the Authorized

TABLE 1

ALASKA PIPELINE OFFICE ORGANIZATION CHART

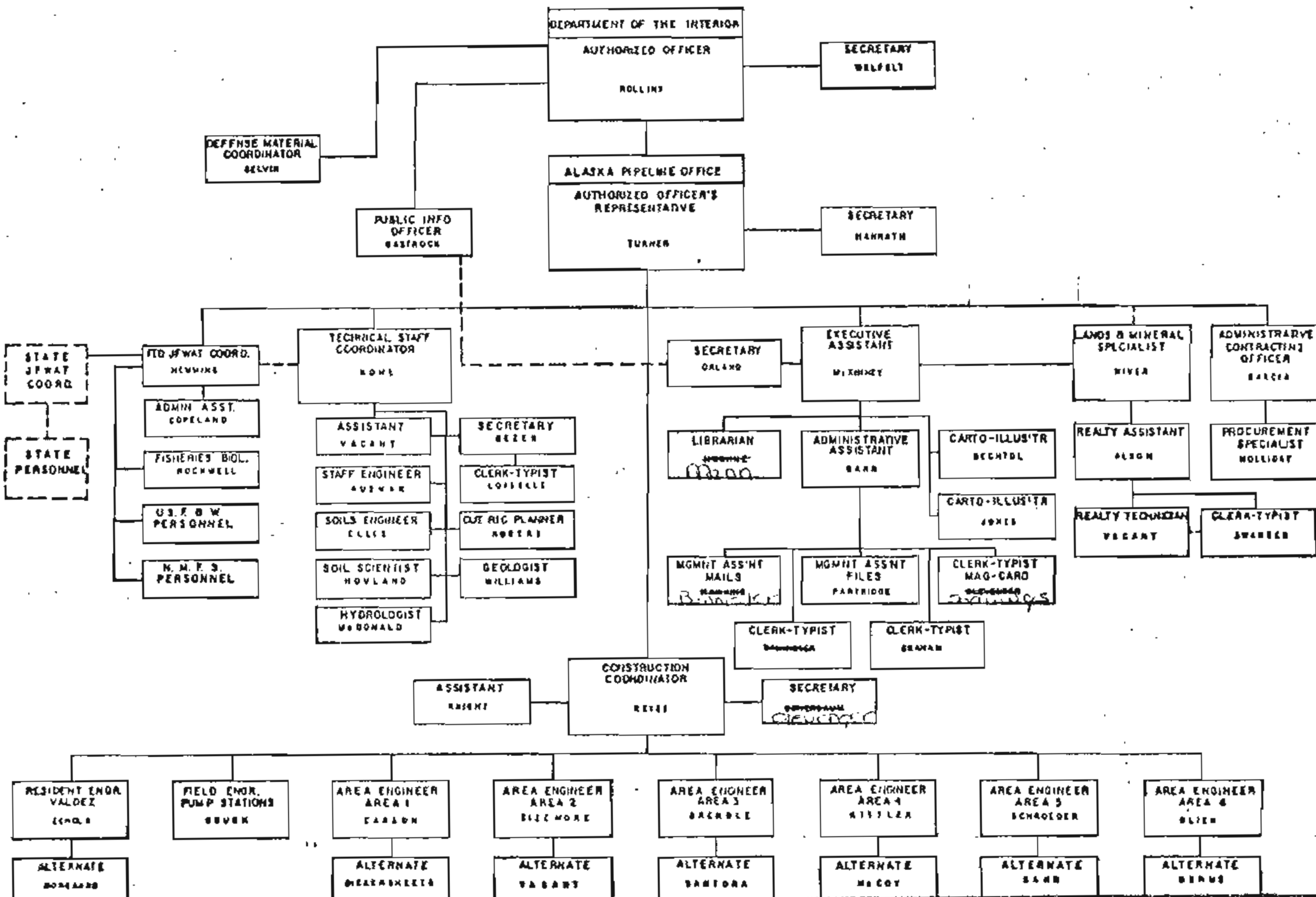
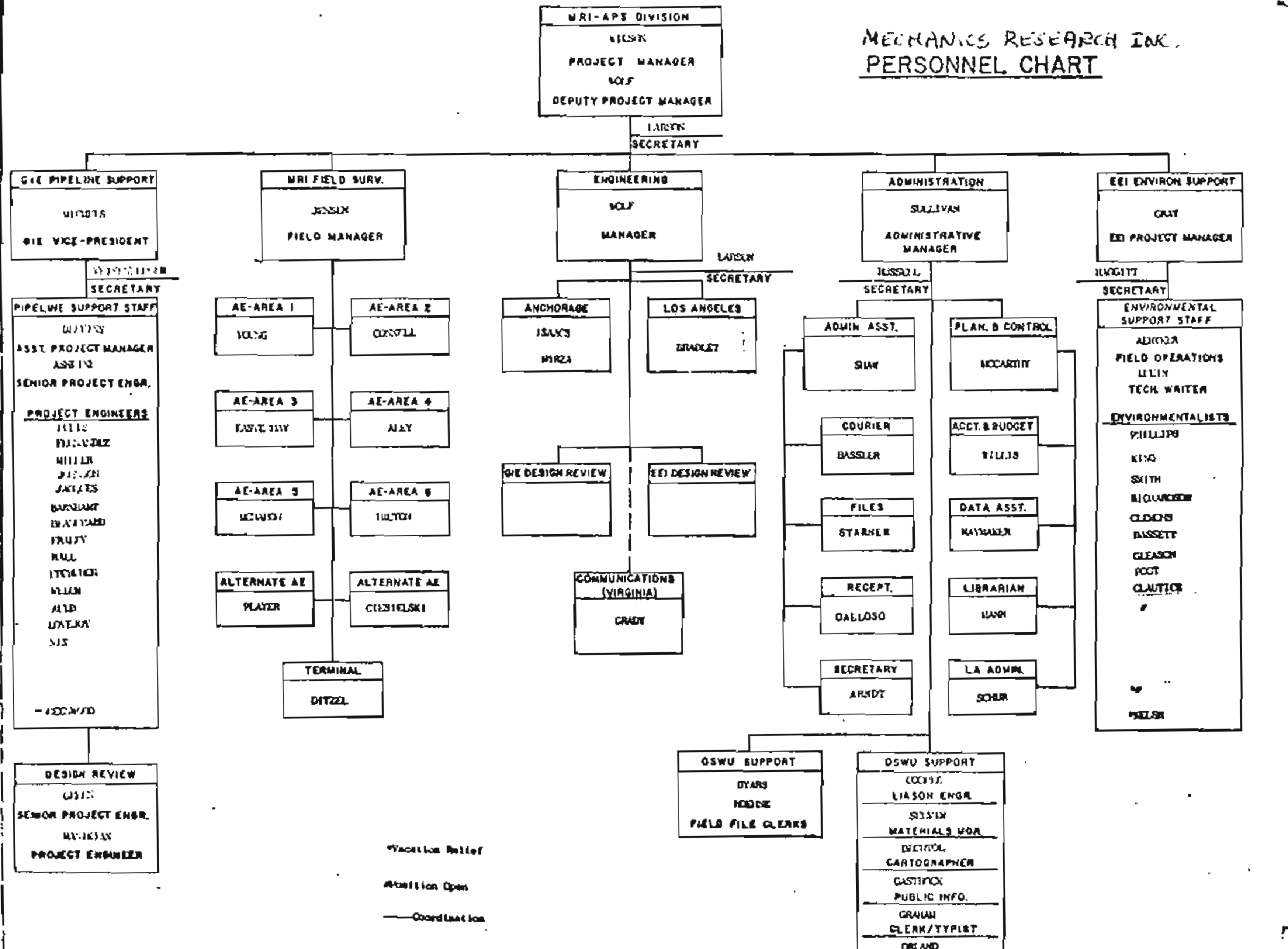


TABLE 2



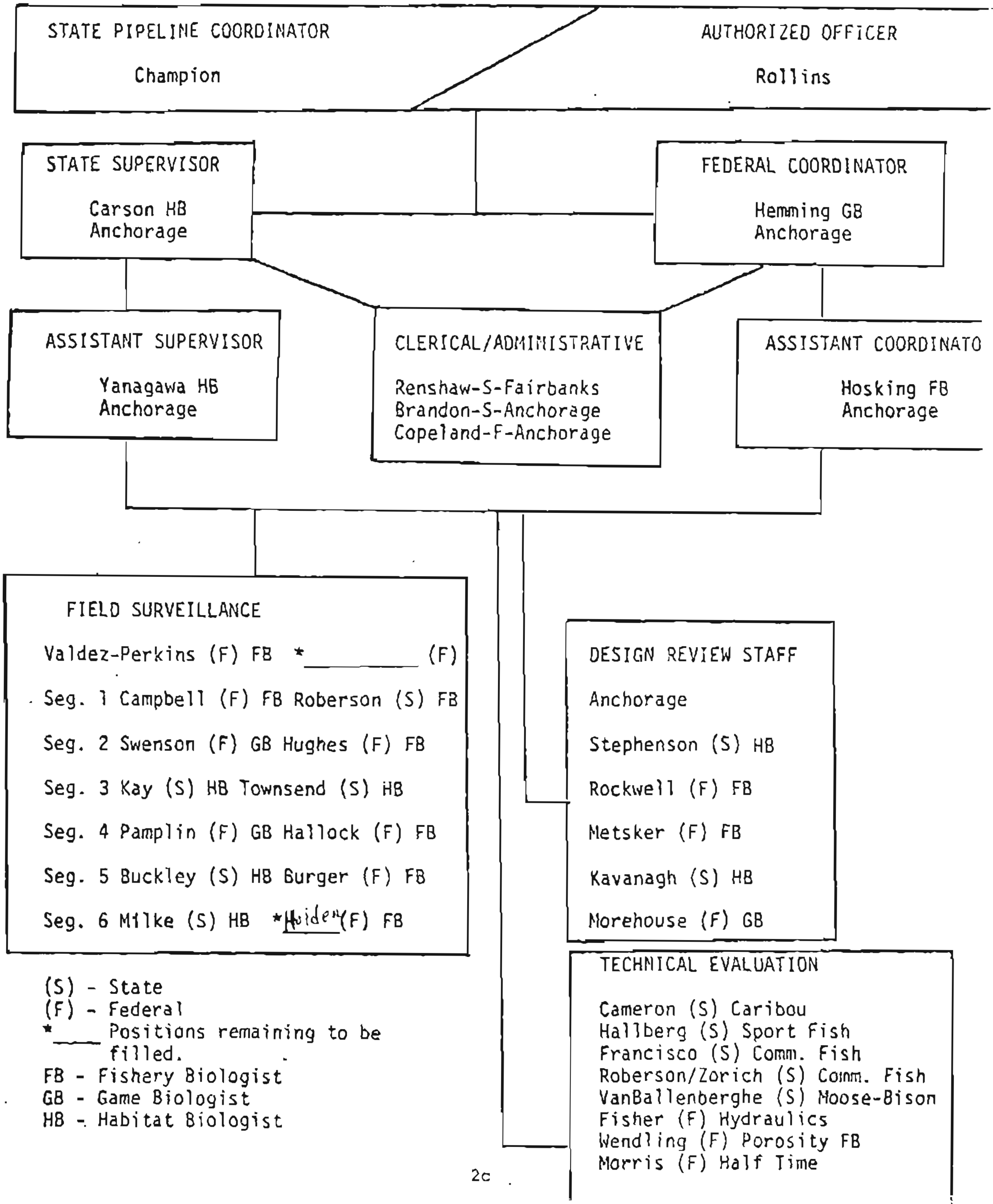
MECHANICS RESEARCH INC.
PERSONNEL CHART
MRI-APS DIVISION
PROJECT MANAGER
DEPUTY PROJECT MANAGER
SECRETARY
G&E PIPELINE SUPPORT
G&E VICE-PRESIDENT
SECRETARY
PIPELINE SUPPORT STAFF
ASST. PROJECT MANAGER
SENIOR PROJECT ENGR.
PROJECT ENGINEERS
MILLER
DESIGN REVIEW
SENIOR PROJECT ENGR.
PROJECT ENGINEER
MRI FIELD SURV.
JENSEN
FIELD MANAGER
AE-AREA 1
YOUNG
AE-AREA 2
AE-AREA 3
AE-AREA 4
AE-AREA 5
AE-AREA 6
ALTERNATE AE
PLAYER
ALTERNATE AE
CIESIELSKI
TERMINAL
DITZEL
ENGINEERING
WOLF
MANAGER
LARSON
SECRETARY
ANCHORAGE
MIRZA
LOS ANGELES
BRADLEY
G&E DESIGN REVIEW
EEI DESIGN REVIEW
COMMUNICATIONS (VIRGINIA)
GRADY
ADMINISTRATION
SULLIVAN
ADMINISTRATIVE MANAGER
SECRETARY
ADMIN ASST.
PLAN. & CONTROL
MCCARTHY
COURIER
BASSLER
ACCT. & BUDGET
FILES
STARNER
DATA ASST.
RECEPT.
DALLOSO
LIBRARIAN
SECRETARY
ARNDT
LA ADMIN.
SCHUR
OSWU SUPPORT
DYARS
FIELD FILE CLERKS
OSWU SUPPORT
LIASON ENGR.
MATERIALS MGR.
CARTOGRAPHER
PUBLIC INFO.
GRAHAM
CLERK/TYPIST
EEI ENVIRON SUPPORT
EEI PROJECT MANAGER
SECRETARY
ENVIRONMENTAL SUPPORT STAFF
FIELD OPERATIONS
TECH WRITER
ENVIRONMENTALISTS
PHILLIPS
KING
SMITH
BASSETT
GLEASON
FOOT
*Vacation Relief
#Position Open
——Coordination

2b

TABLE 3

JOINT STATE/FEDERAL FISH AND WILDLIFE ADVISORY TEAM

ORGANIZATION CHART



Officer's Representative (table 1). The Technical Staff receives all requests for permits and most design change requests from Alyeska and examines each one from the point of view of each discipline represented on the Staff. It evaluates review comments and reports furnished by MRI and its subcontractors and receives advice from JFWAT on fish and wildlife matters. From all of these sources, together with its own experience and research, the Staff prepares a draft Notice to Proceed, draft correspondence, or a review of technical documents and plans submitted by Alyeska. In some cases these drafts result in meetings with the Authorized Officer or his representative to work out an APO position. Even more often, the Staff works out differences directly with Alyeska's technical staff, with or without the presence of Alyeska or APO management. The drafts, together with field-trip memoranda and memoranda for the record of meetings and other discussion, are the written record (backup) that is placed in the APO files for each Notice to Proceed or other action issued. Personnel of the Technical Staff and Authorized Officer's Field Representatives were largely drawn from the Division of Pipeline of the Bureau of Land Management, Corps of Engineers, Bureau of Reclamation, and private firms.

The writer filled a vacancy created by the formal retirement on April 23, 1974, of N. B. Higgs, the original Staff Geologist. This assignment began on July 17, 1974 and ended September 29, 1976. Initially, several months were required in the office and in the field to become effective as a staff member. Opportunities for briefings by Geological Survey personnel who were involved in the project from 1969 to 1974 were limited, and a complete file of pre-permit correspondence and decisions was not available for study in Anchorage. As a result, there was a break in continuity in Survey involvement that proved to be somewhat of a handicap. In addition, APO was without a Staff Geologist for several months during the critical Preliminary Design Review phase of the project.

The Preliminary Design Review, completed in mid-1974, established the construction criteria (Criteria and Design Bases, vols. 1-12) and fixed the route of the pipeline. Little opportunity was available after this time for major reroutes of the line because the time required to survey, design, and do the necessary exploration would have upset construction schedules. APO was successful in obtaining reroutes of the line only where Alyeska had alternatives in mind and could be convinced that time and money could be saved.

Completion of the Preliminary Design Review in mid-1974 left unresolved the following design criteria:

Slope erosion
Deep burial with overlying ice-rich soils
Thaw-plug stability
Shallow slides
Thermal model (Vertical Support Member design)
Thermal piles
Frozen soil strengths
Specially buried pipeline (refrigerated or insulated)
Tank farm dike thermal cracking
Fuel Gas Line

Under the provisions of Stipulation 1.7.2 Preliminary Design Review of the above-listed criteria was waived for consideration in the Final Design Review. A list of unresolved questions and action items resulting from the Final Design Review through February 23, 1976 is included as Appendix C of this report. Among the criteria items listed above, the Fuel Gas Line criteria have been resolved, and the line is under construction. However, the Vertical Support Member (VSM) design was approved only after September 30, 1976 and many other important questions from a pipeline integrity standpoint are still unresolved.

Construction was begun in the spring of 1974 on the haul road under the direction of and to the specifications of Alaska Department of Highways. The road was not under control of Alaska Pipeline Office as to location and construction standards on Federal lands. This created problems later in that long access roads to the pipeline were required in some areas and the road blocked desirable pipeline relocations in others. The function of APO during road construction was in reviewing applications for materials and disposal sites on Federal lands for the Bureau of Land Management, which issued the necessary land use permits. Camp construction at this same time was monitored by Authorized Officer's Field Representatives, assisted by MRI and advised by JFWAT.

Technical Specifications for pipeline, pump stations, and terminal were submitted by Alyeska from mid-1974 to early 1975. Review of those affecting the pipeline was not completed until mid-1975 because of the press of other work. Other documents, such as boring logs, Terrain Unit Maps, Field Design Change Manual, and some of the Environmental documentation and plans were submitted for information or approval beginning in the fall of 1974.

Final Design Review, beginning in mid-October 1974, consisted of examination of a large number of Applications for Notice to Proceed, the first of which were for access roads and for clearing of the right-of-way and construction of the gravel work pad. The Notices to Proceed for clearing and work pad construction required attention to proposed construction mode and subsurface data because the type of clearing and pad construction is different for buried mode than for elevated mode. In some areas the permits and applications were based on meager to scanty subsurface data, and many subsequent design changes have been required by drilling programs that have revealed unexpected conditions or by drilling requested by APO because of expected unfavorable conditions for buried mode. Alyeska deliberately proposed below-ground construction for many questionable areas on the theory that the regulatory agencies would be more willing to grant a change from buried to elevated than a change from elevated to below ground. The Christmas holiday of 1974 brought a flood of Applications for Notice to Proceed for buried construction, elevated supports, elevated construction, access roads, terminal, pump stations, and the first of the river crossings. These applications were keyed to a January 5, 1975, startup of pipeline construction. Overtime work by the Technical Staff was begun in November 1974 and was scheduled on a regular basis until March 31, 1975, when the last of the Notices to Proceed for line pipe was issued. Notices to Proceed were issued with "windows" or "holds" where construction was not allowed without resolution of questions or submittal of backup data supporting Alyeska's design.

As Staff Geologist, the writer during this period worked mostly on Notices to Proceed for below ground construction, right-of-way clearing and work pad construction, some of the river crossings, and pump station and terminal foundations. Contributions were made to other types of Notices to Proceed as needed, and nearly all of the Notices to Proceed were reviewed, other than those that were issued during a 3-week absence due to illness. In August 1975 and again in mid-1976, the writer was asked to revise and update all of the line pipe Notices to Proceed to incorporate closing of "holds" and "windows" and to reflect agreements reached with Alyeska on major problems.

In the spring of 1975 review of Technical Specifications was completed, and the preliminary Quality Control and Preliminary Field Design Change Manuals (4 vols.) were reviewed. Final agreement with Alyeska on all points raised in reviews of these documents has still not been reached.

Applications for permits to cross rivers were handled during the spring and summer of 1975. The two final Notices to Proceed to be issued were those on the Middle Fork Koyukuk River near Wiseman, where complicated legal problems prevented drilling of necessary test holes, and the Yukon River, which required an analysis of the design of the highway bridge as a pipe-support structure.

Scarcely had the Notices to Proceed been issued and construction begun when the need became apparent for a procedure to handle design changes beyond the scope of the Field Design Change Manuals. A system of Design Change Requests, later supplemented by Field Engineering Changes Notices (those designed by Alyeska's field engineering sections), was developed in April 1975 for pipeline construction, so that APO could review and approve most requests. Unfortunately, no parallel system was established for design changes on pump stations and the terminal; however, the more important change requests have been transmitted informally for Staff review through the Authorized Officer's Field Representatives. Processing Design Change Requests and Field Engineering Change Notices in late 1975 and 1976 occupied a significant part of the time of Technical Staff and MRI and resulted in a large number of meetings, particularly when the changes involved criteria or application of unresolved design criteria to the final design.

Early onset of cold weather caused a slow down in construction in late October 1975, and a complete halt to outdoor work by late November. Work resumed in February 1976. During the winter layoff, the paper work continued unabated and included: design change requests; resolution of "holds" or "windows" in the Notices to Proceed; review and discussion of Specifications, Field Design Change Manuals, erosion-control plans, Notice to Proceed applications for pump stations and the terminal, and other specialized proposals. The types of problems under discussion at that time are listed in Appendix C.

By early 1976 the number of strictly geologic problems had been reduced to ground-water and rock-stability at the terminal and Keystone Canyon, fault crossings and monitoring of fault movement and seismic activity, the Yukon River bridge, the crossing of Atigun Pass in the Brooks Range, and proposals for changes in construction mode and relocations in the pipeline. These problems are discussed more fully in Appendix B.

To utilize the time fully, I volunteered to assist the Technical Staff Supervisor in handling Design Change Requests, acted for him in his absence for periods of as much as three weeks, and served as Authorized Officer's Field Representative when needed. Tours as AOFR were done in Section 1 between Valdez and the Gulkana River in June 1975 and August 1976, at the terminal in May 1976, and in Section 5 between the Dietrich River and Galbraith Lake in September 1976.

Throughout the assignment considerable time was spent in the Brooks Range and northward in the search for adequate riprap and in inspection of work in Atigun Pass. As a sideline, I interested myself in the question of camp and pump station water supply, but was not able to follow through by making lengthy field inspection of the drilling of wells. In all, about 80 percent of the time was spent in the office, the remainder on field inspection trips. This proportion proved to be ideal in that it provided the means to keep abreast of field activity, yet provided enough office time to prevent losing battles that were decided in meetings with APO management and Alyeska. In 1976 most of the field trips were inspection of the geologic work at Clearwater Lakes fault, inspection trips to Atigun Pass, and visits to Valdez terminal and Keystone Canyon.

At the request of Alaska Pipeline Office, arrangements were made with the Geological Survey to extend my two-year assignment from July 17, 1976 to September 30, 1976, at which time I returned to Branch of Alaskan Geology offices at Menlo Park, The Pipeline Office has asked that my services be available as needed through completion of the project on a consulting basis; these arrangements are to be worked out directly between APO and Chief, Branch of Alaskan Geology.

Technical and Environmental Stipulations

The Stipulations are appended to the Agreement and Grant of Right-of-Way, the preamble of which states that the environment, effect on people, economic and engineering practicability, and the national need for oil are all things to be considered in constructing the pipeline. This balanced approach to design review and surveillance of the project was generally followed by the management of Alaska Pipeline Office. This management policy is subject to criticism by environmentalists as placing too much emphasis on building the pipeline at the expense of the environment, and by engineers from industry as placing too much emphasis on the environment at considerable unnecessary expense to the project owner companies. Depending on one's training, experience, and personal outlook, neither the Stipulations nor their management is likely to be entirely satisfactory. I have found that the Stipulations were workable, although not completely clear (Appendix A), and that their application by management left only a few points of disagreement.

The Joint State/Federal Fish and Wildlife Advisory Team includes some of the more environmentally oriented personnel on the job, and yet they have also found the Stipulations adequate. They made suggestions for improvement only on the Stipulations concerning quality control, environmental briefings, buffers in waste disposal areas, spawning beds, key fish streams, oil spill contingency plan, drainage structures and culverts, and location of dikes. Their greatest wish was for more than an advisory role; such a role could be given to JFWAT if Alyeska were required to obtain an Alaska Title 16 permit from JFWAT for work in streams.

The fact that Alyeska is free to select the construction mode has caused some problems, particularly in areas where aesthetic niceties and the non-critical needs of big-game animals favor burial of the pipe, but elevated mode is called for in the design. APO position in discussion of these problem areas has been to try to persuade Alyeska to change its design, but not to force Alyeska to do additional drilling or to seek a variance to the Stipulations regarding burial. In one or two cases, where the game-crossing needs were critical according to JFWAT advice, drilling was forced on Alyeska to provide the data for a special buried animal crossing. In other cases, where APO was challenging Alyeska's request for exception to the Stipulation requiring buried river crossings, additional drilling was forced on Alyeska to provide substantiation for their request. The flexibility of the present Stipulations is preferable, even though it generates some disagreement.

Stipulation 3.3.1 regulating burial of the pipeline is subject to different interpretations by different people. Alyeska was inclined to try to read into the Stipulation what they thought the authors intended, rather than what they actually said. Many of the difficulties in administering Stipulation 3.3.1 were resolved when A. H. Lachenbruch's essay on the intent of the Stipulation 3.3.1 was provided to APO staff and Alyeska for guidance.

Stipulation 3.4 on earthquakes and fault displacements was particularly difficult to administer because of lack of experience in the field and lack of background on previous discussions. Some confusion developed because the Stipulation was written at a time when fault crossings had no special design. Terms like "where practicable" and "where technically feasible" (as in Stipulation 3.4.1.2) should be eliminated in the future because they cause unnecessary dispute between the parties over whose definition of practicability or feasibility is correct. For example, in discussing the requirement of Stipulation 3.4.1.2 for seismic monitoring, Alyeska claimed that its design will prevent any oil spill from a rupture of the pipe under the Contingency Plan earthquake, and, therefore, their design is "technically feasible" and the monitoring system is not required.

Additional brief comments on the Stipulations (Appendix A) are those furnished to APO for their evaluation and use.

Organizational changes to improve effectiveness of design review

This discussion is limited to operations of the Technical Staff and its relation with other design review groups. The Staff was deliberately kept one-deep in each discipline as an economy measure. In theory this was a good idea, but in practice the fast pace of processing applications and problem solving requires an alternate for each discipline to provide continuity when the Staff specialist is away on leave or in the field. To remedy this deficiency, the third-party contractor should include an appropriately trained alternate for each APO Staff position on its own staff. On this project, Mechanics Research, Inc. provided its chief scientist, an experienced soils engineer, as backup for APO's soils engineer. His assistant was an experienced geological engineer with training in rock mechanics and engineering water problems which complemented my training and experience. The Staff Engineer, however, relied on several MRI engineering specialists, many of whom were in Los Angeles, and his work was delayed when he was in the field. Attempts to replace him with out-of-town engineers were not entirely successful because the replacements lacked the necessary background and experience in writing the documents required of Staff. The two staff positions requiring greatest outside help during the construction phase of the project were those of the Staff Engineer and the Staff Soils Engineer. An advantage in having the third-party contractor provide the auxiliary staff members is that it seems easier for a private firm to move people in and out in response to workload than it is for a Government organization without disrupting ongoing projects.

The usual difficulties were noted in internal communication and in communication between organizations. Physical separation is a common contributor to poor communication. APO, MRI, and JFWAT, and perhaps even the State Pipeline Coordinator's Office, should have been housed in a single building, but at one time were in three buildings--dictated by the realities of the real estate situation in a boom town. Some of the early design review by MRI was handled in Houston, Edmonton or Calgary, and in Los Angeles. Ineffectiveness of the system was partially remedied by moving the Houston review team to Anchorage. More discussion probably should have been carried on with the State Pipeline Coordinator's Office on important problems being reviewed simultaneously; perhaps, though, independent reviews provided by each agency was the better approach. Communication with Alyeska and its staff was generally good because APO Staff was encouraged to work out solutions with opposite numbers on the Alyeska staff.

A system of Technical Staff letters or memos should have been developed to help the Authorized Officer's Field Representatives interpret conditions of the Notices to Proceed. In a few cases, conditions of the Notices to Proceed went unheeded by the AOFR or were misunderstood. Most of the time, however, the AOFR telephoned his supervisor, the appropriate Staff member, or APO management for answers to questions. Unfortunately, a private APO communications network was not available, and the Alyeska telephone system was overloaded and not always reliable, especially north of the Yukon River.

The Joint/State Federal Fish and Wildlife Advisory Team consisted of 29 professional and 6 non-professional employees. Much of JFWAT's effort, in addition to review and surveillance, was in research to identify the critical fish streams. The first official usable fish stream list keyed to pipeline stationing was submitted to Alyeska in January 1975, and has been amended since. Preparation of the early Notices to Proceed involved identification of fish streams and imposition of specific restrictions to protect fish habitat. After issuing the fish stream list to Alyeska, Notices to Proceed were simplified by elimination of lists of fish streams and the special restrictions which generally reiterated the Stipulations. It would have been helpful to have had the research phase of the project completed or brought to a halt before construction began.

A system of Design Change Requests was set up in April 1975 for the pipeline work, but no parallel system of change requests was established for construction of the pump stations, terminal, communications facilities, and other parts of the system. Both APO and Alyeska's own technical staff brought this problem to the attention of Alyeska's Manager for Engineering. The problem was caused by division of responsibility within Alyeska for design; Alyeska engineering in Anchorage was responsible for design of the pipeline, but Fluor Alaska, Inc. in Anaheim, California, was the designer of the terminal, pump stations, and other facilities. Unless the Authorized Officer's Field Representative on the site short-circuited the system, APO Technical Staff received no design changes for that part of the project designed by Fluor-Alaska. The system must be corrected on future pipelines, and should have been corrected on the present project.

Very soon after establishment of the Design Change Request system, it became apparent that Alyeska's engineering staff in Anchorage was being overloaded by pipeline design change requests from the field. Alyeska delegated considerable responsibility for field design changes to its field engineering staffs in each pipeline section. APO approved the field design change system, but asked that all changes involving pipeline construction modes, land actions, criteria, and specifications be approved by APO in Anchorage and that changes of all kinds be routed from the Alyeska field engineering staff to the AOFR in the field to make sure that APO is aware of the change, to determine which changes need Technical Staff approval, and to provide AOFR input into the staff review. These requests went unheeded by Alyeska, and some of the AOFRs complained they were unaware of the changes until after completion of the work and that the field design change system was used to make variances in the Specifications that applied to entire pipeline sections. Changes of this kind, obviously, cannot be allowed because if they are, each section of the pipeline will be built to different specifications.

On future projects a satisfactory system of handling design change requests should be worked out early in the project, a staff set up to handle the problem at industry and Government levels, and the guidelines clearly established. This is not a Stipulation item, but it should be apparent that enforcement of the Stipulations is impossible if no review is given to design changes in the pump stations, terminal and other facilities, and if the field engineer is allowed to vary from the Specifications without monitoring.

On future projects every effort should be made to complete review of the Technical Specifications, Field Design Change Manual, and criteria items well in advance of construction. This was not done until construction was well advanced. Even though reviews have been completed of these documents, all sections have not been agreed to and are still being argued at a time when the project is 90 percent complete. There is no way the Government can enforce the Stipulations unless instructions to the contractors contained in the Technical Specifications and Field Design Change Manual are agreed on before construction begins. This defect should be remedied in the future by requiring submittal of these documents at least 6 months in advance of planned construction startup and approval before startup.

Assistance from the third-party contractor

As is shown in table 2, Mechanics Research, Inc., the third-party contractor maintained field-level support of its own, Gulf Interstate Engineering, and Ecology and Environment personnel for surveillance. Their design-review function was performed in Anchorage-geotechnical by their own employees, environmental by Ecology and Environment, and pipeline engineering by Gulf Interstate Engineering personnel. MRI stress and mechanical review team in Los Angeles worked with Fluor Alaska on pump stations and terminal. Hydraulic reviews were done by Foundation Engineering Company of Canada. Corrosion expertise was provided by Dr. Scott and welding by Jack Baker, both independent consultants.

Reviews and other work items under the MRI contract were requested by memorandum to MRI from the Contracting Officer's Representative in

APO, and completed reviews incorporating input from MRI subcontractors were submitted by MRI's deputy project manager and head of the engineering group to APO. Initially, the review system did not work well under the press for processing of Notices to Proceed in the Final Design Review under deadlines shorter than the 90 days required in the Stipulations. The situation was improved by moving elements of the Houston review team to Anchorage, where the team could achieve the flexibility in scheduling required. Underachievers in the system were eliminated, and before too many months had passed the system worked reasonably well.

In the field the MRI surveillance team used a system of spot-check reports and remedial action reports that was designed to record all items of inspection made by MRI and its subcontractors, whether unfavorable or not. Computerization of the spot-checks theoretically would permit statistical studies, as well as facilitate recovery of specific inspection reports when needed. The system provided for follow-up checks to see if remedial action had been taken by Alyeska. These reports were submitted daily to the Authorized Officer's Field Representative for action or information, as the case may be, and for his concurrence or non-acceptance. In my tours as AOFR I found that the MRI spot checks were a time-consuming, onerous task that had little present value, though possibly of future value as a record of the work. AOFRs had no equivalent record of inspection, other than that recorded in their official log book and in their field memos to Alyeska.

Considering the difficulty in obtaining experienced personnel for short-term assignment, MRI did a reasonably good recruiting job and had on its own payroll and in its subcontractor (Gulf Interstate Engineering) some excellent engineers, particularly the specialists who assisted the APO Technical Staff in design review. MRI's Area Engineers in the field were largely retired military or Corps of Engineers personnel who had a general engineering background but no pipeline experience. The job of an inspector in the field is not an easy task, and with some exceptions, those who did this work for MRI performed well. Field representatives of Gulf Interstate Engineering were pipeline specialists. Some of the environmentalists of Ecology and Environment and biologists of the Joint State/Federal Fish and Wildlife Advisory Team lacked experience in construction, but many of them adjusted well and learned quickly; those who could not soon lost their effectiveness.

Whether the third-party contractor arrangement is preferable to an all-Government operation would be hard to evaluate unless I were in the management of APO. An all-Government operation would have the advantage of direct line of authority from top to bottom. A third-party arrangement makes it easier to move people--good ones in and bad ones out--which was done throughout the job.

Recommendations for monitoring

I have recommended to Bureau of Land Management that the position of Staff Geologist in Alaska Pipeline Office may be abolished and that the Geological Survey could provide geologic advice as needed during the Operations and Maintenance Phase of the Trans-Alaska Pipeline project. This recommendation was based on the declining need for geologic services during the last year of my assignment. In some matters, such as seismic design review, for example, it might be better to provide APO a specialist in that field, rather than keep a Staff Geologist on the job. An informal arrangement has been made by which APO can request my services as needed by arrangement with Chief, Branch of Alaskan Geology. This will satisfy the near-term need of APO for the remainder of the construction phase and the startup of the line.

Water Resources Division of the Survey has certain ongoing projects that it feels should be continued. These include:

1. Streamflow and water-quality station activities, including physical-chemical and biological studies.
2. Monitoring of streambank and bed erosion and interaction of streams with the construction zone, as per baseline reports.
3. Monitor the effects of the pipeline on icings (aufeis) and the effects of icings on the pipeline.
4. Monitor the impact of operation of the pipeline on water quality, particularly temperature and oil spill effects.
5. Provide contingency funds for case history studies of special areas of impact, such as oil spills like that at Prospect Creek, test holes to check movement of sewage effluent near camps,

accelerated erosion due to construction disturbance.

Continued monitoring of Columbia Glacier would be of interest to the owner companies' marine committee and to the Coast Guard because of the potential for discharging icebergs into the shipping lanes approaching the Valdez terminal. In addition to this study, Water Resources Division will want to continue its glaciological studies along the route and to monitor glacier-outburst floods and their effect on the pipeline.

A program of Arctic Environmental Studies of the Branch of Alaskan Geology, Geologic Division of the U.S. Geological Survey is designed to investigate energy-related corridors, to obtain base-line geotechnical data and engineering-geologic data from construction of the Trans-Alaska Pipeline, with special emphasis on character and distribution of surficial deposits and permafrost, Quaternary stratigraphy, periglacial features, seismic phenomena, and geologic processes that are either unique to or active in the arctic environment. During the Operation and Maintenance phase of the pipeline, observations will be made of geotechnical maintenance and environmental problems to determine the location, character, and extent of the problems and their relationship with geologic conditions and processes. These observations and data collection will permit evaluation of the adequacy of technical stipulations in controlling adverse engineering and environmental impacts, and make it possible to improve stipulations for future projects.

Under this program, the Survey could, if interested in such studies, monitor development of the thaw bulb beneath the elevated and buried line and note increases in moisture in the thaw bulb that might lead to failure. It could examine potentially unstable cuts, such as those at Squirrel

Creek and Klutina River, to determine whether the thermal piles can maintain enough frozen ground to prevent downslope movement of the thaw bulb beneath the work pad. Opportunities exist for studies of rock stability and relation to pore pressures at the Terminal and in cuts like those at Keystone Canyon. Avalanches, slush flows, and mudflows along the line in the Atigun River valley are a little-known potential hazard and might provide a suitable subject for research in the monitoring effort. Survey seismologists may be interested in data from the Alyeska's seismic monitoring system to be installed at Pump Stations 1, 4, 5-12, and at the Terminal.

The question was asked early on the construction phase of the project whether the Survey should log the pipeline trench. Because the trench was open only a short time and was open simultaneously in many different areas, it was impossible for me to do this. And, it would have taken a large crew of Survey people to log the 325 miles of buried line. At the time, the Survey did not have the personnel to do the job. However, the Bureau of Mines had been logging the trench, particularly between Fairbanks and the Yukon River, where rock outcrops are sparse and where there is some expectation of mineralization. My recommendation has been that for most areas the expenditure of time and money would not be worthwhile. Alyeska has ditch logs that will be available for inspection. The ditch logs, test holes, and other geologic information are in a data bank which will eventually be available for research purposes. At the present time, however, Alyeska is trying to sell the data to one of the gas pipeline companies for use in installing a parallel gas line and is reluctant to make the data available. That part of these data not already available should be obtained as soon as possible as part of the base-line and construction data collection programs of the Arctic Environmental Studies program.

Cold Regions Research and Engineering Laboratory, U.S. Army, has begun an eight-part research program on the pipeline to evaluate the interaction of man's activities with physics, mechanics, behavior, and characteristics of cold regions conditions (CRREL Progress Rept. 76-A, Nov. 1975). The general fields of inquiry are:

1. Impact of construction on terrain and streams, including effect of mining stream beds for construction materials; impact of bridges, groins, and dikes on stream regimen; and effects of water impoundment and vegetation removal on terrain.
2. Evaluation and measurement of effectiveness of construction equipment, including procedures for blasting, ripping, and excavation of permafrost.
3. Design, construction, operation, and maintenance of temporary and permanent camps and other facilities, particularly the suitability of prefabricated buildings under cold conditions.
4. Observation and documentation of performance of erosion-control techniques, structures, and revegetation measures.
5. Investigation of design criteria and parameters influencing the performance of roads and airfields in areas of severe climate, unfavorable soils, seasonal frost and permafrost.
6. Correlation of performance and design criteria for slope stability and settlement in areas directly influenced by pipeline and related construction and subject to subsequent thawing.

7. Foundation design, installation, and performance evaluation, with emphasis on the Vertical Support Members, valves, bridges, and pump stations. Ground-temperature sensors are planned for 500 VSMs, three refrigerated foundations, and five miles of buried pipeline.
8. Analysis of design and operation of terminal and pump stations, along with pumps, valves, tanks, grounding, cathodic protection, heating and cooling, communications, and oil-spill contingency plans.

APO Notices to Proceed and approved Design Change Requests specify certain requirements for monitoring performance of the pipeline in areas where there is concern for the design efficiency or where soil conditions are marginal. These will be summarized in the final reports of APO and provided to the Alyeska O&M group. Alyeska has its own proposals for monitoring the pipeline design, particularly the Vertical Support Member design under different soil and climatic conditions; they will doubtless discover other monitoring needs as the O&M inspection gets underway. The pipeline will be surveyed accurately. Deflections in the buried pipe are to be measured by the curvature pig, also called the "superpig". To date, progress on development of the superpig has not reached the point at which it can measure curvature and deflection of the pipe with sufficient accuracy to confirm promises of its performance. In addition, Alyeska seems reluctant to make a base-line or as-built run of the superpig by which all later curvature and deflection measurements can be compared. However, APO is pressuring Alyeska to make such a run.

Role of the U.S. Geological Survey in future pipeline projects

The Geological Survey should be involved in future pipeline projects, as it has been in the Trans-Alaska oil pipeline project. Its participation should start at the very beginning in evaluation of alternate routes and selection of the final route. It should be involved in site selection for pump stations and terminals; evaluations of the effect of the project on natural resources, terrain, and environmental disturbance; and in evaluation and identification of geologic, seismic, and hydrologic hazards. It should be involved in the search for favorable foundations, suitable materials for construction, and water supplies, and should evaluate groundwater conditions of construction sites, potential aurfeis areas, special flood conditions, potential scour on streams, and areas subject to mudflows, slush flows, and avalanches. It should provide basic geologic and hydrologic data, and topographic mapping as required to evaluate potential routes and the effect of the project on the environment. Products of Survey input should be presented and phrased in such a way as to be readily understood by planners, decision makers, and engineers in Government and industry, and, above all, should be delivered on schedule.

Most of these activities were carried on for the present project. The Government's role in selecting the alignment on Federal lands was one of approval of the alignment chosen by Alyeska. The Survey should be in a position to present geologic and hydrologic information and appraisals of the environmental and construction problems of alternate routes submitted as a guide to the Government in approving a route that is both environmentally sound, yet feasible from an engineering standpoint.

In a sense, the Geological Survey is also serving the Trans-Alaska Pipeline project in a third-party contractor role, as is the Corps of Engineers through its Waterways Experiment Station and its Cold Regions Research and Engineering Laboratory. As a Technical Staff member, the resources of the Survey have been available as needed, just as the Corps of Engineers groups have assisted the Staff Hydrologist and Staff Soils Engineer, respectively. In most cases the very short deadlines for decisions have made it impracticable to call on Survey expertise. Most of the problems have been site-specific and, therefore, not resolvable by consultation without field inspection. I have taken advantage of every opportunity to obtain outside help and acknowledge the following persons' work on the problems indicated: George Plafker for field studies of suspected active faults in the Brown Creek area near Valdez; O. J. Ferrians, Jr., and Reuben Kachadoorian for briefings on general problems and field examination of the Yukon River bridge foundation problem; T. D. Hamilton and F. R. Weber of the Survey and R. D. Reger of the Alaska Geological and Geophysical Survey for assistance with the Clearwater Lakes fault problem and geology of the Delta River area; F. R. Weber for locations of suitable riprap in the Delta River valley; R. M. Chapman for maps and discussion of the Yukon River bridge foundations and nearby potentially active faults; H. N. Reiser and W. P. Brosgé for discussions of geology of the Brooks Range and potential sources of riprap; and R. A. Page and H. W. Coulter for background on early decisions and discussion and for their reviews of the seismic design of the Yukon River bridge and the fault displacement and seismic monitoring systems. Throughout the assignment discussion of water problems was furnished by Joseph Childers and Charles Sloan of Water Resources Division. Two trips were made to Menlo Park--February 1975 and January 1976--for consultation with Survey personnel.

The Geological Survey should be represented on the Technical Staff of a design review and surveillance agency that monitors any future pipeline--at least as long as questions related to Survey input into the preliminary phases of the project are likely to be discussed and decided on. Therefore, it is important that the Survey representative on such a group be familiar with the early discussions, either through participation in them or through a very thorough briefing. As a late-comer to the Trans-Alaska Pipeline project, I felt handicapped by lack of the necessary background in my discussions with Alyeska engineers who had been with the project since the beginning. There were times, though, when lack of participation in the early phases of the work was an advantage, in that my position had not already been compromised by being party to earlier decisions.

If the Geological Survey chooses not to be represented on the group that monitors construction, it will lose any voice in following through on its input into the early phases of the project. If the Survey is available on a consulting basis, the chances are that the fast pace of decision making during the first year will make consultation impracticable. My suggestion is that the Survey be represented on the design review and surveillance group for the first year or so, until all the major problems concerning routing and mode of construction are resolved. After that time, the Survey representative could be replaced by consultant specialists in ground water, seismology, rock mechanics or whatever problems face the group. The pace of deciding these later, more specialized problems is slower and time would be available to call in the necessary consultants.

The decision of the Survey not to effect my transfer to Bureau of Land Management for this two-year assignment was correct in that it permitted greater freedom of expression and action than might have been possible if my future career depended on the goodwill of APO management. I believe that maintenance of a connection to the parent organization also facilitates access to information and expertise available from that organization. These arrangements should be continued by the Survey on future assignments to an organization like Alaska Pipeline Office.

Geologic maps prepared for future projects are needed at two levels--a general purpose planning map emphasizing foundation conditions, availability of materials, hazards, and environmental considerations, and a more detailed map showing detailed materials and foundation conditions preferably at a scale compatible with the construction drawings. On the Trans-Alaska Pipeline project the 1:125,000 strip maps prepared by the Survey were intended for use in planning the project. Detailed maps at 1 inch=1,000 feet were prepared for Alyeska by R&M Consultants on a photomosaic base. During the construction phase of the project the Survey maps were used only for identification of rock types in the search for suitable riprap. The Survey maps were not compatible with the scale of the construction drawings and were too generalized for use in design review. The photomosaic maps prepared by R&M Consultants were scale-compatible, and had the necessary detail that suited them for design review.

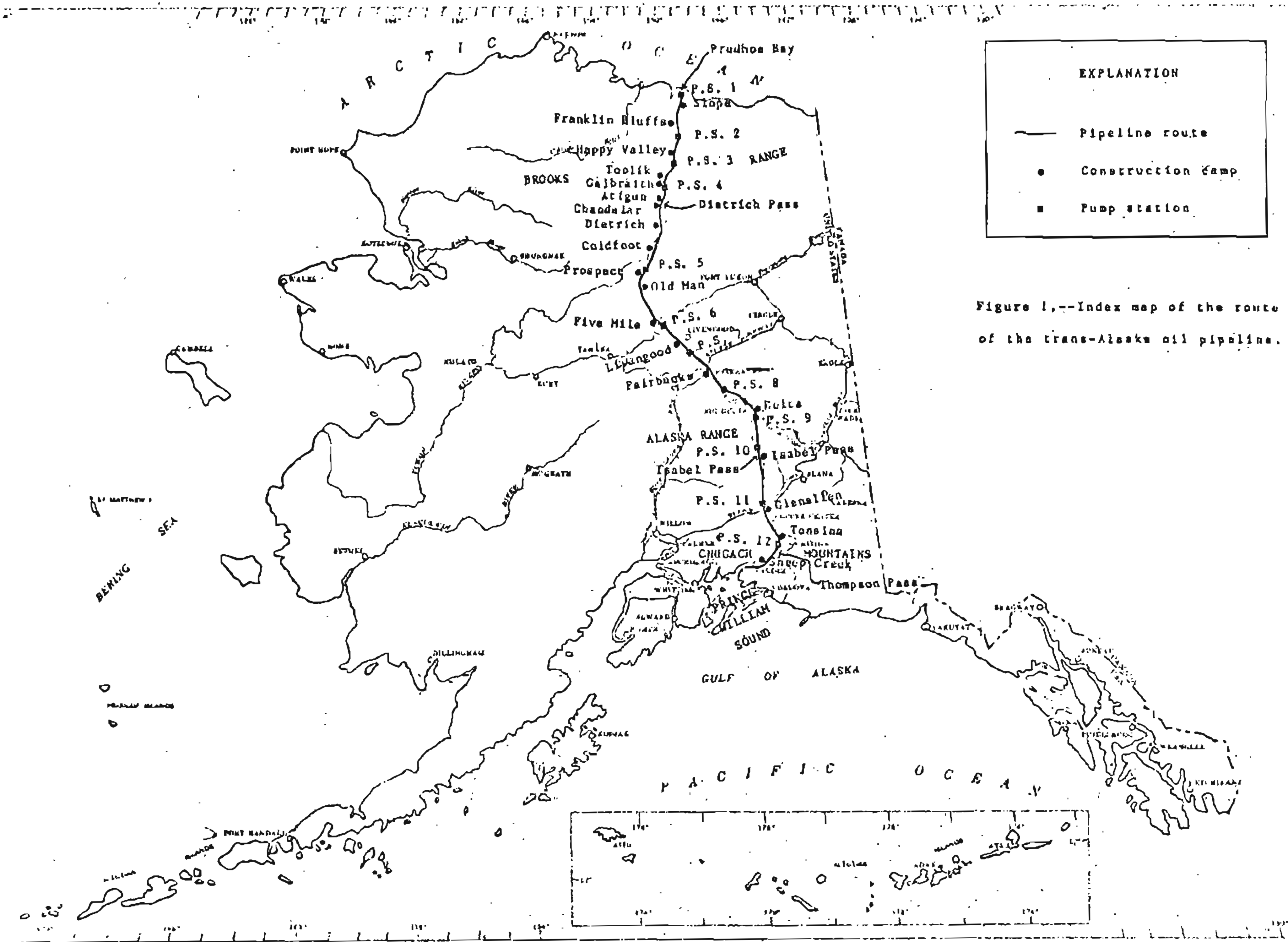


Figure 1.--Index map of the route of the trans-Alaska oil pipeline.

On future projects, consideration should be given to use of a map that can be read directly by the non-geologist, rather than a map with a standard time-dependent geologic legend. Two approaches can be used: (1) use a map explanation that rates the map units in terms of favorability, identifies the potential construction problems and environmental considerations directly on the map; or (2) use a map explanation that identifies the materials, e.g., gravel, till, thaw-stable silt, ice-rich silt, etc., as a system of patterns, with colors indicating relative favorability for construction, and shows the flood, avalanche, and other hazards directly on the map by use of symbols.

APPENDIX A

Comments on individual Stipulations

Stipulation	Comment
1.1	Rearrange definitions into logical grouping and order.
1.1.1.1.	Access roads: In the future haul roads, such as the Yukon to Prudhoe Bay road, should be constructed as part of pipeline system and designed accordingly to (1) provide a single road/pipeline corridor, (2) provide convenient access to the pipeline or use as workpad in buried sections, and (3) design the road so not to restrict or limit pipeline alignment changes.
1.1.1.7	Commissioning--should also include definition of "start-up".
1.1.1.10	APO now has 6 construction subdivisions; Alyeska has shifted to 5 by combining sections 5 and 6. Confusing--wonder if Stipulation has been followed strictly.
1.1.1.12	All items listed have not been furnished as part of the Final Design, and often are not referenced completely. Most can be obtained on request, but only if we know about them.
1.1.1.15	NTP permission to begin construction--Stipulation does not mention field "turn on" by Authorized Officer's Field Representative, which is an administrative procedure of APO.
1.3.1	Line 2: Change "call upon" to <u>require</u> (stronger).
1.4.2	Is this necessary in view of 1.4.1--a legal problem?
1.6.3	Correct mailing address.
1.6.5	Correct mailing address.
1.7.1	Desirable, but not always followed; apparently no action taken on violations.
1.7.1.2	NTPs have been issued consistently when operation proposals have not been submitted.
1.7.1.4	Schedule of submissions (of NTPAs) was not followed or even done (waived?), and APO was overloaded by mass submittals and post-submittal changes in priority. Thus some NTPAs required longer than the 90-day limit to process.
1.7.3.1	Adherence to a SNAD was hard because Alyeska had trouble keeping up to date with changes in schedule of field work. Largely given up or waived after 1975 and replaced with Alyeska's construction schedule.
1.7.4.1	A waiver was granted for Preliminary Design Review of unresolved items, deferring consideration until Final Design Review.
1.7.4.2	Designs in Atigun Pass were reviewed without proper maps because pipeline centerline survey had been completed and plotted on airphotos.

Stipulation	Comment
1.7.4.3(2,3) (4)	Usually referenced, but not always supplied unless requested; DNADs and permits--slack adherence to Stipulation on these.
1.7.4.5	See comment for 1.7.1.4.
1.10	Definition of Completion of Use should be included in 1.1. Is the date oil line is no longer needed and is dismantled or when construction is completed?
1.10.1	What are the deadlines for submittal of restoration plans?
1.15.2	Vague. State and Corps Engineers (also Coast Guard) permits are required on streams. What is definition of a stream, of small craft?
1.18.4	Yukon-Prudhoe Bay haul road is not included, by definition. Does this assume State maintenance?
2.1.1	Good to have. Did not hear of any environmental briefings.
2.2.2.2.	Does prohibition of use of mobile equipment on rivers and lakes exclude or include winter operations?
2.3.2.1.	Does protective screen include the Yukon-Prudhoe Bay haul road (to be a state highway)? Not clear because status of road is not clearly defined in other Stipulations.
2.4.1.3.	The work pad was not designed to avoid or minimize disturbance to thermal regime and probably could not be and still be constructible.
2.4.3.2	Do low water crossings violate the requirement for use of fill ramps rather than cutting of stream banks? These low water crossings were agreed to by JFWAT as a substitute for culverts.
2.5.2.2 & 2.5.2.3	Where is documentation of Fish Spawning Beds. JFWAT asks that overwintering areas be included.
2.5.3.1	Critical list of fish streams was not completed in time for effective planning and delay caused much confusion and contradiction. Identify streams before construction.
2.11.1	Blasting permits were delegated to AOFRs.
2.11.2	Necessary? There is already a requirement for obtaining all necessary State and Federal permits. Combine with 2.11.1.
2.14.3	Define "start-up" under 1.1.
3.2.2.2	Seems out of place. Damage to ground organic layer should be put with damage to vegetation in Stip. 2.4.1.1.
3.2.3.2	Need to apply for BLM use permit for access roads?
3.3.1	Superpig and monitoring Programs have not been developed as of date of issue of NTPs.
3.3.1(4)	Differences in interpretation of this section took place in the matter of overexcavation and backfilling to reduce thaw settlement and in placing centerline of pipe below level of thaw unstable material. Enforcement was uneven at first, but improved after receipt of Lachenbruch's essay on intent of Stipulation. Needs clarification and rewording.

Stipulation	Comment
3.3.1	Intent of Footnote 3 not entirely clear to me.
3.4.1.1	Delete phrase "where technically feasible". Debatable depending on point of view of individual.
3.4.1.2	See comment 3.4.1.1.
3.4.2.1	No statement has been received from Alyeska on risk assessment.
3.4.2.2	Needs considerable clarification.
3.4.2.3	Useful only on buried crossings.
3.5.1	In whose judgment is avoiding the hazard "not practicable", Alyeska's or the Authorized Officer's?
3.6.1.2.1	Design of road bridges to 50-year flood is foolish if road bridge is upstream from pipeline bridge designed to project design flood.
3.6.2.2	Stip. 2.4.3.2 says that ramps should be used for temporary access. Why not clarify by combining these two Stipulations?
3.8.1	Can be deleted, if surging glaciers are added as another geologic hazard under Stip. 3.5.1 and damage from outburst floods be included under calculation of project design floods as per Stip. 3.6.1.1.2.
3.9.2	I don't recall seeing these plans, procedures, and quality controls unless they are satisfied by criteria documents.
3.11.2	Who has defined the critical areas for containment dikes? Change reference to 2.14 to 2.14.1.
All	Try to avoid all uses of terms such as "practicable", "technically feasible", etc. These do no more than cause arguments, in enforcing Stipulations.

APPENDIX B

Problems related to work of the U.S. Geological Survey

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APPENDIX B

Problems related to work of the U.S. Geological Survey

1.0 General Statement

This appendix discusses some representative problems related to the work of the Geological Survey and summarizes their solutions in meetings or agreements between APO and Alyeska. It is appended to the report to give an overview of the type of problems in which the Geological Survey is likely to become involved if it chooses to participate in future pipeline projects, and, by means of selected case histories, shows the type of give-and-take in meetings between APO and Alyeska that led to solutions. Naturally, it is not possible to provide all the details of these discussions, but additional information can be provided from records on file with Branch of Alaskan Geology, if desired.

2.0 Terminal

The terminal, located on the lower slopes of the Chugach Mountains that border the south shore of Valdez Arm, has had geotechnical problems that include rock slope stability, excess overburden, ground-water pressures, lack of adequate construction materials, water supply and power, disposal of excess material, and stability of the fill in disposal sites at the base of the mountains and along the shore of Valdez Arm.

Rocks of the Valdez group at the terminal include units of massive graywacke, greenstone, mixed graywacke and phyllite, and phyllite. The graywacke and greenstone are generally firm and are suitable for most construction purposes, but the phyllite is weak and crumbles when dug with a power shovel. The rocks dip about 60° north and form dip slopes in most of the cuts that back the tank farms and other installations. The strike is east-west, parallel to the shore of Valdez Arm. These rocks are mantled by as much as 80 feet of till.

Stability of the rock slopes at the terminal is a major problem. The Fort Liscum landslide, a massive late-glacial slide, is located along the eastern edge of the terminal site. Studies show that the slide is now apparently stable and that it did not move during the 1964 earthquake. Studies of airphotos of the mountainside back of the terminal indicate possible failures high on the slopes, but these have not been substantiated by ground studies. The possibility has to be kept in mind that a failure similar to the Fort Liscum slide could occur in the terminal area, but the chances of such a major slide in the 30-year life of the project are so remote that the problem was not an issue.

Rock slides involving 12,000 cubic yards of phyllite took place in the cut behind the power plant and vapor recovery building on September 7, 1975. The initial failure of 5,000 cubic yards in midslope undercut the upper 60 feet of the cut slope which contained several rows of rebar rock anchors. The undercut portion of the slope failed some six hours later. A third failure on September 10 involved a 2-ft. thick slab on the upper portion of the slope. The failure was apparently along a shallow-dipping fracture surface inclined toward the face of the cut. Contributary causes for the failure were given as: (1) undulations in foliation being daylighted at the base of the cut; (2) blasting for the interceptor trench at the base of the cut; (3) high ground-water pore pressure in the rock; (4) absence of planned rock reinforcement; and (5) partially constructed rock drainage system. An extensive program of rock bolting and drain holes to dewater the rock, together with buttressing the lower part of the cut, is designed to prevent recurrence of failures along the wedges created by the shallow-dipping fracture systems. Unless the rock can be dewatered completely, the slope will not be stable under the contingency plan earthquake (0.6g). Dewatering will consist of drilling drain holes in the cut face and diversion of a stream upslope that is thought by Alyeska to supply water to the rock. A seal will be placed at the top of such cuts to prevent infiltration of surface water.

A second failure in a cut in phyllite took place June 17 and 19, 1976, behind the West Manifold Building. The failure, involving about 1,500 cubic yards of rock, was bounded on the lower edge by a vertical fault intersecting the cut face, and it extended upward to the top of the bench, removing about three to six feet of rock as measured normal to the foliation. The failure occurred before the rock bolting program and weep holes had been completed. Alyeska did not put in bolts or weep holes to relieve hydrostatic pressure as the cut was constructed downward from the top of the bench, and some of the bolts involved in the failure were only 15 feet long, compared to the 25- to 30-ft. lengths required for the spacing used.

APO continues to be concerned about rock stability problems, even though Alyeska has retained A. J. Hendron and Michal Dukovansky (Dames and Moore). R. P. Benson of Klohn-Leonoff Consultants, Ltd. examined the cuts for MRI and concluded that the cuts suit the geology well and that no major problems are foreseen. However, Benson believes that additional drainage of the cuts may be necessary when the piezometric measurements are analyzed. The main problem areas are cuts behind the power and vapor recovery buildings, the west manifold area, the ballast water treatment building and tanks, and the west tank farm (tanks 16 and 18).

An unexpectedly large amount of overburden was discovered when excavation of the terminal was begun. Apparently exploratory drilling was concentrated on rocky knobs that were more easily accessible to helicopters and did not reveal the excessively thick till in the intervening valleys. Nearly a million cubic yards of waste material required disposal. Some was placed in a disposal site at the base of the mountain, uphill from the construction camp. A stream provided water to liquefy the material causing it to flow onto a haul road, where dikes were constructed to contain the flow. The remainder was placed as a fill of the cove west and south of Jackson Point and elsewhere along the shore to straighten the shoreline. So great was the quantity of waste material that proposals were advanced at one point to dump it in deep parts of Valdez Arm, in Shoup Bay, and in the ocean; none of these proposals was carried out.

Stability of the disposal site at the base of the mountain and the fill in the cove near Jackson Point is questionable under earthquake loading. Sudden slippage of the fill in the cove could generate waves that might damage nearby piers or waiting tankers. Wave damage caused by failure of sections of deltas in other parts of Valdez Arm has been considered in designing the docks and mooring facilities.

Since 1975, MRI has 32 unresolved outstanding non-conformance spot check reports on the following problems at the terminal: (1) The asphalt seal beneath some storage tanks has been damaged due to excessive groundwater pressure; (2) The presence of moisture beneath the tanks threatens to corrode the thin bottom plates of the tanks; and (3) Ringwalls of tanks 16 and 18 were founded on pedestal-type mud mats (still under review). In addition, small diesel tanks 55 and 56 were built on fill material containing ice and snow. This problem was corrected beneath tank 55 by removal of the crushed rock within and outside the ring wall, but that beneath tank 56 was considered not significant. Both tanks have been hydrotested successfully.

High vertical embankments of reinforced earth backfilled with permeable shot rock have been used in the east tank farm and on the slope overlooking the vital control building. APO has been concerned with the design and has asked that piezometers be installed to insure that no buildup of water pressure is taking place. The embankment above the control building has a calculated movement of about 5 inches under contingency plan earthquake loading of 0.6 *g*, according to Alyeska's designers.

Some difficulty was encountered at first in locating a source of graywacke or greenstone suitable for use in diking and for riprap. The first quarry site selected was drilled and found to contain unsuitable mixtures of graywacke and phyllite; quarrying would have left a very high cut face behind the east tank farm. Later, a safer location was found where graywacke could be quarried.

Water supply is taken from a gallery on Allison Creek near the apex of its alluvial fan at the east edge of the terminal site. One of the problems considered in establishing this supply was depletion of streamflow by pumping the gallery during the low flow period below the five cubic feet per second deemed necessary for protection of the fisheries resource. A lake at the head of the creek is a good alternate water source that could have provided the necessary head for fire protection. The lake could have been used as the source of water to supply hydro-electric power, utilizing the difference in head between the lake and the terminal area.

3.0 Rock stability Keystone Canyon

A study of jointing and foliation of the rocks in Keystone Canyon by N. B. Higgs, the first APO Staff Geologist, was directed toward the possibility of placing the pipeline in tunnels, instead of its present position in conspicuous view along a high bench on the east wall of the canyon. One of Higgs' conclusions was that the walls of the canyon have been stable, even during great earthquakes, because the rock fractures do not daylight in the canyon. On the other hand, concern has been expressed for the safety of the pipeline in its present position on the bench by T. R. Magorian, a geophysicist with Ecology and Environment, Inc., because of the possibility of failure along joint planes that he believes are daylighted in the canyon. To resolve the conflicting opinions and to be sure that Alyeska was aware of this possible problem and was investigating it, appropriate phrases were inserted into the Notice to Proceed, calling attention to the integrity questions on State land. Alyeska assigned Bob Watters, a rock mechanic, to investigate the problem, and he agrees with Higgs' report. Watters' letter and his report of rock stability in pipeline cuts along the bench describe fractures that intersect to form unstable wedges that would be dangerous to work crews, but he finds no danger of massive rock failures that would drop the pipeline into the canyon.

The highest and most unstable of the cuts along the present pipeline route in Keystone Canyon are Site 2 (Sta. 965+00 to 967+00) and Gobbler's Knob (Sta. 927+40 to 928+65). Overhangs and unstable rock wedges posed a danger to workmen deepening the cuts and constructing the pipeline. Fortunately, no falls took place, even though the pipe was laid before the cuts could be stabilized. Alyeska's engineers believe the cuts can be brought down and laid back without having the debris overstress the buried pipe.

4.0 Summary of pump station foundations

Foundations for Pump Stations 1, 2, and 3 are designed as refrigerated systems on frozen alluvium or lake bed deposits. Pump Station 4 is built on limestone of the Lisburne Group. Pump Station 5 is on sand and gravel that apparently is silty and ice rich at depth and requires refrigeration. Pump Station 6 has been a major problem; at least 13 feet of overexcavation was required in the tank farm area to reach igneous rock beneath ice-rich siltstone of the Rampart Group. In the pump building and camp area, ice-rich organic silt and siltstone are too thick to be excavated, and the foundations must be refrigerated. Pump Station 7 has been relocated to a site where the foundations are on shale or argillite. Pump Station 8 is located on deeply weathered schist, marble, quartzite, and gneiss. Pump Stations 9 and 10 are on gravel, but the original doubts about the safety of Pump Station 10 from floods and earthquake risk remain. Pump Station 11 is on terrace gravel overlying glaciolacustrine deposits, and slope stability problems have been noted in cuts made in glaciolacustrine silt bordering the terrace. Pump Station 12 has some liquefiable sand within the sequence of sand and gravel beneath the station. A surface layer of ice-rich lacustrine silt was removed from part of the site. Station 12 is located near a slope failure that took place as a result of liquefaction during the 1964 earthquake. As pointed out in early reviews of the project, the station should have been moved to a site having bedrock foundations. This could have been done as part of the Little Tonsina reroute on the east side of the valley if delay of the project could have been avoided by adopting this reroute.

5.0 River crossings

River crossings have been applied for by Alyeska as separate Notice to Proceed packages, each of different design to meet the local conditions. Many changes in these designs have been required for geotechnical reasons, as described below. Stipulation 3.6.1.1.1.1 requires that all crossings be buried unless justification for elevated construction can be made convincing to the regulatory agencies. Many holes were drilled as part of an extensive program in 1974 to confirm Alyeska's designs; many others have been drilled for the same purpose at the request of APO.

Hydrostatic testing of the pipeline has shown that the pipe has become deformed or buckled beneath some river crossings so that the pig cannot pass through. Causes of the deformation are thought to be the manner in which some of the crossings were installed under winter conditions by forcing the pipe down with backhoes, problems with river weights, or perhaps freezing of the ground around the empty pipe. In some crossings installed in winter, ice layers have been discovered beneath the pipe that, when melted, may cause deformation. These problems were under study when I left the job, and repair work was underway.

5.1 Middle Fork Koyukuk River near Wiseman

This crossing was probably the most complicated of those reviewed because of legal restraints on private mining claims and the need for court action to clear the right-of-way. The 1974 design called for an elevated structure designed to the Project Design Flood immediately downstream from a highway bridge designed to the 50-year flood. This incongruity, and knowledge from existing borings beneath the river of unfrozen ground beneath the active floodplain, led to the suggestion by APO that the crossing be changed to a buried design, provided that additional test holes along the northwest bank confirmed the proposed relocation in unfrozen ground of the transition from elevated line to a buried crossing. The owner refused permission to drill these holes, and Alyeska went to court without further discussion with APO Staff, but adopted the suggestion for a buried crossing. State Court in Fairbanks awarded the requested right-of-way to Alyeska on August 29, 1975. This decision locked Alyeska into an alignment at an angle to the river, which was not suitable for an elevated crossing.

From the date of the court decision until January 5, 1976, Alyeska section engineers arranged for test holes to confirm the transition point of their revised buried design on the southeast bank, and only one hole at the transition point on the northwest bank. Alyeska's new design for the crossing placed the northwest bank transition well out into the active floodplain in a position where it lay directly in the path of water channelled beneath the highway bridge. Unsuitability of this design had been related to Alyeska informally as early as April 1975. An analysis requested of backwater behind the roadfill and the possibilities of breaching the roadfill west of the bridge and the effect on the training structures at the transition had not been submitted; no centerline borings had been drilled beneath the river for a distance of 2,300 feet on the new alignment. Existing borings near the crossing showed that surficial gravel rests on glaciolacustrine clay, clayey silt, and sandy silt of unknown thickness. Some of the confirmation holes on the southeast bank, where gravel is thinnest, show that the silty material is fluid and rises in test holes. This indicated that difficulty might be encountered in keeping the trench open.

Despite all these design problems, no effort was made to resolve them until a meeting in mid-January 1976, when the contractor began pressuring Alyeska for authorization to proceed. The purpose of the meeting was to pressure APO into issuing the Notice to Proceed.

At that meeting APO insisted on adequate test holes across the river on the centerline of the crossing and agreed on 300-ft. spacing. Test pitting was suggested as a means of determining whether the silty material would be stable in the trench walls. Finally, APO insisted on moving the west bank transition point at least 100 feet toward the northwest bank to remove it from direct attack by water passing through the highway bridge. Alyeska insisted this could not be done. APO and its contractors suggested a way to change the elevated design northwest of the river to allow the shift and requested a test hole at the new transition point. The other unresolved problems were discussed at this and later meetings.

The centerline drilling program confirmed unfrozen ground at the relocated transition and elsewhere beneath the active channel, except beyond at the southeast bank where ice-rich permafrost in fine-grained deposits required relocation of the transition point 200 to 300 feet toward the river. Drillholes at the southeastern 500 feet of active floodplain encountered plastically frozen fine-grained material to a depth of about 25 to 30 feet. Further meetings were held in which APO agreed to the location of both transition points and required still more holes and trenching to define the extent of permafrost beneath the southeast 500 feet of the active floodplain. These holes found that saturated material occurred at 25 or 30 feet. A specially designed trench, overexcavated to 30 feet and backfilled with gravel was used to carry the buried pipe across the short section of frozen ground.

5.2 Prospect Creek

The crossing of Prospect Creek was originally designed to be buried in unfrozen gravel or in shallow bedrock. However, test borings drilled to confirm the design of the transition south of the creek showed that thick ice-rich till or glacial-lake sediments filled an old channel in the bedrock surface. These unfavorable materials required elevated construction so close to the stream that it was impracticable to provide transition to the buried crossing. A new application for elevated crossing was requested from Alyeska by APO, along with an application for variance to Stipulation 3.6.1.1.1.1 which would be a matter of form to grant. The new design is still deficient in that the bridge steel is too low with respect to the Project Design Flood and the pilings are not deep enough for anticipated scour.

5.3 Jim River

The pipeline was routed through the Jim River floodplain, rather than over the high ground along the east bank, because favorable soils for burial were expected. JFWAT objected to construction in the floodplain of this rich fish stream. Additional test borings showed that sections of the floodplain alluvium are underlain by frozen silty material (till or glaciolacustrine sediments?), and a crossing of Jim River Slough must be elevated. A new application for Notice to Proceed has been requested to reflect these design changes. The upset conditions became apparent too late to engineer a major reroute to avoid elevated construction in the floodplain.

5.4 South Fork Koyukuk River

The 1974 mode confirmation program showed that frozen ground occurs in the alluvium and underlying fine-grained lacustrine(?) deposits at the South Fork Koyukuk River crossing. The crossing was redesigned from buried to elevated.

5.5 Gulkana River

The Gulkana River is a rich salmon-spawning stream and is on the National list of Wild and Scenic Rivers. The crossing was originally designed as a refrigerated buried stream crossing in which the west bank transition from elevated to buried mode was located on the inside of a meander loop. The pipe within the meander loop would have been subject to erosion by the stream if an upstream meander cutoff took place. The pipe beneath the river channel was to have been buried in soft, unfrozen glaciolacustrine clay within the thaw bulb. Insulated refrigeration lines, leading from a refrigeration plant on the east bank, were designed to cross under the river to prevent thaw of frozen clay at the edge of the thaw bulb on the west side of the river. The contractor informed Alyeska that this complicated crossing design was unbuildable, particularly if siltation of the river was not allowed. Alyeska transferred the contract from Price to Morrison-Knudson and asked that the crossing be approved via a bridge at a new location on a stable straight reach of the river downstream from the former site. Fabrication of the steel for the bridge was authorized in January 1976, with delivery from Japan scheduled on March 18. Construction was completed before breakup of 1976. This shows that a major redesign could be done in a short time, if necessary.

5.6 Sagavanirktok River

The four crossings of the Sagavanirktok River were originally designed as elevated structures, complete with elaborate causeways, fills, training structures, and narrow openings which tend to constrict flow of the river. Review of the boring data showed that the crossings were in thaw stable or unfrozen material and that they could be buried. Burial during a construction period limited by fish and raptor restrictions has not been easy. Early arrival of cold weather in the fall of 1975 caused many difficulties in keeping the trench unfrozen, and some of the work was delayed until spring 1976. During the spring, the pipe in the southernmost crossing floated to the surface. It had been crushed by some unknown process and was replaced. Despite the construction problems, redesign to buried mode will save thousands of yards of riprap, all hauled from a quarry at least 30 miles distant. In retrospect, two of these crossings should have been eliminated by rerouting the line.

5.7 Middle Fork Koyukuk River and Hammond River

Drilling for these crossings located an unusually thick sequence of silt--locally thicker than 150 feet--beneath the surface alluvium. The deposits are locally frozen and are liquefiable. Specially designed long piling had to be used to obtain the necessary bearing to support structures in this type of material.

5.8 Salcha River

The scour depth originally proposed by Alyeska has been recalculated based on recent U.S. Geological Survey work and the pipe is now buried deeper.

5.9 Yukon River

The pipeline is designed to cross the Yukon River on the State Highway bridge, anchored at Pier 4, and resting on specially designed supports. As a pipeline support structure it has been necessary to review the design of the bridge and its foundations, despite objections of State and Federal Highway officials. The review has been long and hampered by inability to obtain design calculations easily, but it has been thorough, as shown by some of the questions under discussion in one of the meetings just before issuing the Notice to Proceed:

(a) Effect of greater permissible longitudinal displacement of the superstructure on the stresses in the pier frames.

(b) Downdrag on wingwalls and backs of the abutments due to thaw settlement of the soils.

(c) Potential for liquefaction of soils at the abutments.

(d) Maintenance of adequate prestress in the anchors on each pier. (Note: The State's bridge designer states that the anchor bolts provide an additional margin of safety against overturning due to ice forces, and it is not necessary to maintain a fixed stress on the anchors.)

(e) Different earthquake response of Pier 4 from that originally assumed because of different foundation conditions (shear zone under Pier 4).

(f) Prediction of future behavior of the shear zone under Pier 4.

(g) Scour and its effect on the soft gouge beneath part of Pier 4; is riprap necessary to protect against scour?

(h) Ice loading (Design was considered conservative).

The question of activity of the shear zone beneath Pier 4 and proximity of active faults to the bridge has been discussed with R. M. Chapman of the Survey. There is no doubt that the Minook Creek fault, seven miles west of the bridge is seismically active, but no ground breakage has been noted near the pipeline. The Kaltag fault, which is active west of Tanana, lacks ground breakage and concentrated epicenters east of Tanana. No definite evidence for the location of the fault near the bridge is available. Chapman agrees with me and with Alyeska's geologists that the shear zone beneath Pier 4 is similar to shear zones found elsewhere in rocks of the Rampart Group and is not necessarily an indication of an active fault.

6.0 <u>Remode of pipeline in areas of dense upland till</u>

Dense, cobbly to bouldery, silty sandy gravel having a silt content of more than 6 percent, yet a dry density well in excess of 100 pcf is a common type of glacial till in the end moraines and ground moraine near Donnelly Dome north of the Alaska Range and from the Alaska Range south to near Hogan Hill. At one point, when Alyeska was trying to economize by burying additional segments of the line, a proposal was made to seek a variance to Stipulation 3.3.1 to permit burial in till having a silt content greater than 6 percent by weight passing the No. 200 U.S. Standard Sieve. A section of the line from Beal's Cache past Donnelly Dome to near Black Rapids Lodge was selected for study. Existing test holes showed that most of the material was free of ice, had high density, and low thaw settlement.

Approval for remode to buried was given contingent on additional test work, and excepted certain kettlehole areas in which silt content was very much more than allowed in the Stipulation, and in which the deposits had high ice content. The test holes showed that additional areas were unfavorable for burial, so that the remode would have been a jumble of alternating above-ground and below-ground segments. In addition, one transition from above to below ground pipe would have been within the Donnelly Dome fault zone. This would have required redesign of the fault crossing. For these reasons, Alyeska abandoned its attempt to remode the line, and constructed the entire segment above ground, as desirable as some buried segments would have been from aesthetic and game passage aspects.

At a much later date, Alyeska wished to reconsider its mode assignments in the area between the Alaska Range and Hogan Hill, where part of the line had been approved for burial during the early design review. In this case, Alyeska wished to remode the entire segment to elevated construction, even though several 2,000- to 3,000-ft. long sections on south-facing slopes and in valleys appeared from test holes on 500-ft. centers to be free of permafrost. APO wanted to leave some of these segments buried for game passage, but Alyeska argued that they could not be sure that upset conditions would not be found unless the test holes were on 100-ft. centers, and they were unwilling to perform the additional drilling. Desirable as these long game crossings would have been, APO felt that the Stipulations did not give them the right to dictate the construction mode and did not want to force Alyeska into a situation in which a last-minute variance to Stipulation 3.3.1 would be necessary. The remode to elevated was granted with the proviso that additional sagbend game crossings would be constructed in critical game areas designated by JFWAT. During the discussions of this remode, Alyeska engineers stated that 7 of the 10 remodes in questionable soils had not worked out, and that the indecision in design had caused Alyeska considerable expense, particularly in the area between Beal's Cache and Donnelly Roadhouse.

7.0 Material site investigations

7.1 Sand and gravel

Material sites were selected by Michael Baker, Jr., Inc., consultant to Alyeska, and were evaluated by Division of Pipeline of Bureau of Land Management and by Alaska Pipeline Office as an ongoing process beginning in 1973 and continuing into 1974. The purpose of these evaluations was to determine the quality and quantity of materials and the environmental impact of the sites for use in granting the necessary land-use permits by Bureau of Land Management. Material from sites selected for the haul road was on a free-use basis, and that used for the pipeline was on a bid basis, the usual price being around 18¢ per cubic yard, except in one case in which a disgruntled ex-employee is reported to have bid the price up to 64¢ per yard. Land and Minerals Section (Bureau of Land Management) attached to APO maintained detailed records of gravel use from each pit and processed permit applications and applications for expansion of pits. Most of the evaluations by APO Technical Staff on behalf of Land and Minerals Section were based on familiarity with the area in the field, airphoto interpretation, and review of the applications, rather than on detailed field examination. Occasional field trips were made to locate gravel sources in difficult areas.

In late 1975 and early 1976, APO reviewed applications by the Alaska Department of Highways and by Alyeska for material sites to be used during the Operations and Maintenance phase of the project. The list of pits and riprap sites was pared down to about one every 12 miles, usually near a camp or pump station. These will be negotiated further as the O&M is developed by Alyeska and plans for use of the haul road are clarified.

As it worked out in the field, not all material sites that were approved were used. Some proved to be of poor quality, to be extensively frozen and difficult to work, or not needed. The better sites were expanded as experience proved their worth.

Material sites were mined according to the type of equipment the contractor had on the job. For example, if the contractor had scraper spreads, the pits were characteristically shallow and of wide lateral extent. In such cases, terrain disturbance could have been minimized by use of truck and loader or truck and dragline spreads. There seemed to be objection by Bureau of Land Management to mining gravel below the water table, which increased the disturbed area unnecessarily. I tried to encourage mining of gravel terrace escarpments where more than 20 feet of gravel could be obtained per square foot of terrain disturbance, but was usually frustrated by equipment constraints.

7.2 Riprap

Availability of suitable rock for use as riprap has been more of a problem in the Brooks Range and Arctic slope segments of the pipeline than in any other segment. At the terminal, after some initial difficulty in locating a quarry site, one was established in massive graywacke that proved adequate. Through the Chugach Range the need for riprap is relatively small, and suitable rock is locally available. The Copper River basin segment of the line is largely overland, with need for stone only at the major river crossings. Basaltic greenstone near the confluence of Phelan Creek and Delta River and near Black Rapids Glacier is the source of riprap facing on training structures along Delta River and Phelan Creek. The route is largely overland from the Tanana River to the Yukon River, and only small stone is needed along the small, sluggish streams of that region. Between the Yukon River and Middle Fork Koyukuk River near Coldfoot, the line crosses only small streams, and the minimal requirements for riprap can be supplied from local material sites, such as pits in igneous rocks near the Kanuti River or by quarrying the quartzite member of the schistose rocks elsewhere. In the Coldfoot area, quarries in greenstone and mafic igneous rocks are located south of the camp and in schist and quartzite to the north.

Problems of obtaining riprap are more difficult to solve north of Coldfoot, particularly in the Dietrich River valley which is in a belt of soft phyllite and limestone. Outcrops of limestone of the Lisburne Group are available in the Dietrich River valley west of the mouth of Nutirwik Creek, but were not developed because of poor accessibility. Most of the riprap used in the upper Dietrich River valley was taken from a quarry (Material Site 106.1.1) in a limestone unit within the phyllite sequence a few miles south of Nutirwik Creek. The few outcrops of mafic igneous rocks or diabase sills and dikes are located too high on the mountainsides in the Dietrich River valley to be economically developed. Alternate sources in the Skajit limestone were examined in valleys east of the Dietrich River but the cleavage was too strongly developed to make satisfactory riprap.

In the Atigun Pass area about 20,000 cubic yards of sandstone and fine conglomerate that was excess from roadwork was used as road fill on the upper Dietrich River. This material could have been stockpiled for use as riprap to defend the buried pipeline along the small creek on the south slopes of the pass. The best rock in the Atigun River valley is the thin bed of Kanayut conglomerate available at three convenient sites mapped by H. N. Reiser and colleagues of the Survey. Of the three sites, Material Site 112.3.1, near the haul road, is being used to supply most of the large stone needed for structures along the Sagavanirktok River.

Despite an extensive search by air and ground, no practicable source of riprap has been located north of Galbraith Lake. The best of the sites investigated is Material Site 117.2 between Toolik Camp and Slope Mountain, where resistant ridges of weak sandstone and minor interbedded shale and conglomerate rise above the till-covered upland. These rocks fail the standard tests for riprap and those suggested by the California Department of Highways. They have been rejected by APO, even for sites where access for inspection and repair is available and where the structures are not to be buried or are below water. Alyeska has suggested sites at Sagwon Bluffs and Slope Mountain, but the rocks are so weak they become disaggregated en route to the laboratory. Use of gabions has been considered as an alternative to the long haul of riprap from the Atigun River valley to the Sagavanirktok River. Remoding of the four Sagavanirktok River crossings to buried construction has drastically reduced requirements for riprap, and current plans are to haul from Material Site 112.3.1.

A tabulation of results of testing of riprap is given to show the general range of rock quality under consideration.

TABULATION OF RIPRAP TEST RESULTS

TABLE 4

Location	Specific Gravity	Absorption - %	Durability Index	Sodium Sulphate- % loss*	Los Angeles Abrasion- % loss	Durability/Absorption Ratio	Rock Type	Pass/ Fail
Terminal Quarry	2.74	0.4	74	0	18	53	Greywacke	Pass
A.S. 3 - Sta. 793	2.71	0.7	76	0	27	45	Greywacke	Pass
A.S. 4 - Sta. 906	2.73	0.5	74	0	23	49	Greywacke	Pass
MS. 5-2, Exp. No. 1	2.75	0.4	76	0	18	54	Greywacke	Pass
A.S. 6 - Sta. 251	2.67	1.0	43	1	26	22	Greenstone	Pass
M.S. 7-2M, Exp.No. 2	2.73	0.7	73	0	21	43	Greywacke	Pass
A.S. 7-Tsina Lodge Area	2.92	0.7	46	1	20	27	Greenstone	Pass
A.S. 7-Tsina Lodge Area	2.88	0.6	37	-	--	23	Greenstone	Pass
A.S. 7-Tsina Lodge Area	2.78	1.0	43	0	29	22	Greenstone, Foliated	Pass
A.S. 8 - Sta. 515	2.72	0.6	37	0	23	23	Greenstone	Pass
A.S. 8 - Sta. 790	2.73	0.5	50	0	23	33	Greenstone	Pass
M.S. 14-0	3.19	- -	--	2	15	--	Ultrabasic Igneous	Pass
M.S. 37-3N	3.06	0.3	82	0	17	63	Greenstone	Pass
M.S. 28-0	3.01	0.4	76	0	26	54	Greenstone	Pass
M.S. 28-2N	2.61	0.8	78	0	40	43	Diorite	Pass
M.S. 33-1.1	3.01	0.3	76	1	10	58	Meta-Sedimentary	Pass
M.S. 37-0.1	2.77	0.4	74	-	--	53	Volcaniclastic	Pass
M.S. 39-1.1	2.93	0.3	74	2	19	60	Greenstone	Pass
M.S. 51-1	- --	(2.6)	45	10	--	13	Metamorphic, Weathered	(Fail
M.S. 54-1	2.64	(2.3)	40	-	--	13	Gneiss, Weathered	(Fail
M.S. 54-1	- --	- -	--	4	54	--	Gneiss, Weathered	
M.S. 56-1	2.68	1.1	40	2	41	19	Metamorphic, Weathered	Pass
A.S. 59 - Brown's Hill Quarry (Commercial)	2.80	1.3	82	2	16	36	Basalt	Pass
M.S. 64-2	2.66	1.0	59	-	--	30	Schist	Pass
M.S. 64-2	- --	- -	--	7	36	--	Schist	
M.S. 83-1	2.64	0.4	87	0	21	62	Gneiss and Schist	Pass
M.S. 94-0.2	2.61	0.8	85	0	44	47	Granitic	Pass
M.S. 100-2.1	2.70	0.4	78	0	30	56	Schist	Pass
M.S. 106-1.1	2.73	0.4	30	0	27	21	Marble	Pass
M.S. 112-3.1	2.67	0.6	87	3	19	54	Conglomerate	Pass
M.S. 117-2	2.61	(2.4)	38	(83)	34	11	Sandstone	(Fail
M.S. 117-2	2.63	(2.1)	33	4	20	11	Siltstone	(Fail
	2.5 Min	2.0 Max		10 Max	50 Max			

NOTE: Results as of November 15, 1975.

* 0 represents less than 0.5% loss as reported by laboratory.

8.0 Seismic and earthquake design criteria

8.1 Seismic design criteria

Problems of review of these criteria have been the most difficult part of my assignment with Alaska Pipeline Office because I have had no briefings and no easy access in Anchorage to the written record and oral understandings made on this subject by the Survey, Alyeska, the Department, and others between 1969 and 1974. It would have been helpful, time permitting, to review the file of these documents stored in Menlo Park.

My understanding of the early background of development of the seismic criteria is still imperfect. Coulter and Page's Circular 672 (1972) was written to provide the ground-motion design parameters for use by Alyeska in its design of the pipeline and that Alyeska was to supply a risk analysis. About this same time N. M. Newmark, consultant to Alyeska, was developing the design philosophy and parameters that are part of Vol. 12, Appendices, Criteria and Design Bases of Alyeska. In May 1973, the president of Alyeska requested approval of the seismic and stress criteria so that design could proceed. In December 1973, a letter was sent by the Department of Interior to Alyeska approving these criteria unconditionally.

One of the first tasks of Alaska Pipeline Office was approval of criteria items and the preliminary design (January 23 to July 22, 1974). Because the Department's letter to Alyeska had already approved the seismic criteria, additional review of the seismic design was not considered necessary. However, Mechanics Research, Inc. engaged John Wiggins to look over the seismic design. Among the questions raised in Wiggins' report was inadequate duration, particularly as it applies to liquefaction of soils and slope failures, and the lack of an evaluation by Alyeska of the risk involved in their design. Wiggins proposed formulating a risk analysis, but was not retained for the work.

In 1973, during Final Design review, it became apparent that the status of the seismic criteria was not entirely clear, and in July 1975 I furnished H. R. Peyton of Alyeska and N. M. Newmark, their consultant, the following documents with an informal request for discussion of unresolved questions: (1) R. A. Page's March 3, 1973 review of Newmark's work; (2) Wiggins' report for response to the duration and risk questions; and (3) Page's and Coulter's reviews of the Alyeska fault and seismic monitoring proposals.

On December 9, 1975, I set up an in-house meeting attended by APO management, Technical Staff, and MRI to discuss the criteria questions and any unanswered items. As a result of the meeting a formal request was sent to Alyeska asking for a response to the Wiggins, Coulter and Page reviews and comments that were transmitted informally in July. In early 1976 Alyeska's response was discussed. At this time MRI reviewers had developed some questions on the shoe design for elevated fault crossings and on the ability of the Vertical Support Members to withstand earthquake loading. I combined some of my residual questions with those of Paul Gillespie of MRI and drafted a letter to Alyeska outlining the remaining issues to be solved. In doing this, we were asked by APO management not to raise the issue of a Stipulated versus voluntary seismic monitoring system, which would be treated separately. Meetings were held with Alyeska in June and July, and the list of questions formally sent to Alyeska on August 4, 1976 (APO Letter 1728, next pages). These were the last discussions on this issue before I left the job, and final resolution will have to be up to others, who are working on review of the communications system and the seismic monitoring system, and to APO management.

8.2 Design of active fault crossings

Under the provisions of Stipulation 3.4.2, Alyeska engaged Woodward and Lundgren (now Woodward-Clyde & Associates) to conduct a study of the pipeline route to identify all active faults that might be potential hazards. To be considered active, according to criteria developed by Woodward-Clyde & Associates, the fault should exhibit ground breakage at or near the pipeline route. The results of this study were published as Vol. 8, Appendices, Criteria and Design Bases. The criteria selected for active faults eleminated from consideration seismically active lineaments or faults in the Chena and Salcha River valleys and along Minook Creek. Maximum credible values were established for vertical and horizontal

(B-23A follows)

COPY

Mr. J. F. McPhail
Manager, Engineering
Alyeska Pipeline Service Company
1835 South Bragaw Street
Anchorage, Alaska 99504

In reply refer to:
S.N. P001-APO-1728
Questions on Seismic Design

References:
(1) P001-APO-1283, Questions on Seismic Design, 12/11/75.

(2) Letter No. 1618, Response to APO Questions on Seismic Design 5/12/76.

(3) EAM-4078, Response to R.A. Page Comments on Earthquake Monitoring System, 6/3/76.

(4) APSC Report, "Analysis of the Donnelly Dome Fault Crossing", by C. Kaliappan, dated February, 1975.

(5) APSC Report, (Analysis of McGinnis Glacier Fault Crossing", by C. Kaliappan, dated February, 1975.

(6) APSC Report, "Denali Fault Design for the Trans-Alaska Pipeline System", Appendix A-3.1006, Rev. 1, April, 1975.

(7) APO Letter S.N. P001-APO-802, "Fault Crossing Review", to F. Therrell from M. Turner, dated June 12, 1975.

(8) Alyeska Letter 1530, "Earthquake Monitoring System", dated March 18, 1976.

Dear Mr. McPhail:

Alyeska has recently responded to several areas of concern with respect to applications of seismic design criteria. This letter provides a summary of the status of seismic related questions. In Letter Reference No. 1, a request was made to Alyeska for comments concerning various questions on fault crossings, monitoring systems, the Yukon River Bridge, and monitoring system reviews by H. W. Coulter and R. A. Page. On

April 19, 1976, a meeting was held at the APO to clarify which questions were outstanding. Alyeska provided responses (Reference No. 2) to four agreed upon areas of concern and to a review of the Earthquake Monitoring System by R. A. Page (Reference No. 3). Part of these responses were discussed in a meeting at the APO on 3 June 1976 along with a presentation of a preliminary analysis to verify APO questions regarding the high vertical and lateral loading induced into the elevated support system during ground motion.

Following is a summary of the items of concern and their status:

(1) Yukon River Bridge
The APO is satisfied that all seismic questions pertaining to the Yukon River Bridge have been resolved.

(2) Earthquake Monitoring System

Alyeska has taken the position that the proposed Earthquake Monitoring system is a voluntary system and is not required by Stipulations (Reference No. 8). This topic will be addressed separately and is not discussed herein.

(3) Terminal Supervisory Control System NTPA, EMS Review Comments

The Earthquake Monitoring System (EMS) forms a part of the Terminal Supervisory Control System NTPA submitted package. APO review comments with respect to the EMS are summarized briefly here. This is a listing of items which may be included in the NTP and is not intended as a request for action at this time.

(a) Provide a detailed description of the techniques which will be used to compute spectral response levels along the line at locations other than those with seismic sensor packages. Include a discussion of uncertainty values and inaccuracies associated with estimation of earthquake focal distance from the line, attenuation factors, and other major parameters. These uncertainties and inaccuracies may be "best guess" values and may themselves be imprecise. Relative inaccuracy estimates will be of value even though they cannot be totally substantiated.

(b) Provide site-specific information concerning the effects of subsurface soil characteristics on accelerometer responses.

(c) Provide detailed information concerning operational procedures and/or computer software which will be used to tell control center operators how to use the seismic response data, along with leak detection data to take specific action in the event of a large earthquake.

(d) Consideration should be given to providing peak (acceleration) measuring "scratch" guages or other inexpensive, low maintenance devices at intermediate locations between monitoring sites such as at Remote Gate Valve locations which are accessible for manual retrieval after an earthquake. Such devices could provide an after-the-fact check to improve confidence in estimating techniques.

(e) Confirmation is requested that the supervisory control system includes an automatic pipeline system shutdown following critical events, possibly including seismic events, if not acknowledged by a Valdez operator within a specific period of time. Supporting rationale for triggering levels and timing period is a subject of future discussion.

(4) Fault Monitoring

The APO agrees that fault monitoring equipment is not required in the unrestrained, aboveground pipeline within the Denali, Donnelly Dome, and McGinnis Glacier Fault zones. Measurements of pipeline alignment and settlement will be used to determine the effect of fault movements. Requirements for monitoring the Clearwater Lake Fault Zone will be eliminated if it is reclassified from an active fault to lineament.

(5) Seismic Design Criteria

(a) Risk Assessment

Alyeska should provide a quantitative assessment of risk of oil spillage so that the APO will have a basis for making a decision of what is acceptable. An expansion of Newmark's discussion in Appendix B (A-2.1051A, Criteria and Design Bases), Pages 29-30, could provide the main elements for this analysis. The failure probabilities, given a contingency level earthquake, should be broken out separately for the effects of earth shaking, ground deformation, and earth movement.

(b) Duration of Earthquake Motion

Provide a detailed analysis of the way in which earthquake duration is used in determining landslide and liquefaction potential. Based on this liquefaction model, show that 40 seconds of continuous strong earthquake motion is equivalent to a 90-second duration real earthquake.

(c) Maximum Credible Shift for the Denali Fault

Some confusion has been generated about the actual maximum credible horizontal and vertical shift on the Denali Fault - do we accept the 30-foot horizontal and 7-foot vertical shift as given in Vol. 8, C and DB, 1974, or is the more recently published value of 15 m (48.75 ft) to be used? By prior agreement, Alyeska is to check the feasibility of altering the design shift from 20-feet horizontal and 5-feet vertical shift to values closer to the maximum credible shift.

(6) Design Verification of Support Structures

In early 1975, Alyeska presented design analyses for each of the three pipeline fault crossings, References 4, 5, and 6. These reports were reviewed and found to be satisfactory except for the following concerns:

(a) Capability of the interior support shoe in the pipe support system to carry the very high vertical and lateral loads predicted for the static plus fault displacement load case.

(b) Anticipated strain levels in the pipe wall would actually exceed the strain value of 0.8 percent (which establishes wrinkling as per C and DB Appendix A-3.1080, Vol. 4). rather than being below 0.8 percent as stated in References 4, 5, and 6. This implies that the pipe may wrinkle, but not necessarily rupture to cause spillage of oil.

APO Letter No. 802, Reference 7, requested that Alyeska discuss the effects of high loads on the pipe supports.

The APO staff is available to work with Alyeska to arrive at a timely resolution of these questions.

Very truly yours,

/S/ MORRIS J. TURNER

Authorized Officer's Representative

cc: Mr. John Latz
Mr. C. A. Champion
Mr. Cesar Deleon
JFWAT, TSC, CC, MRI
All AEs
All AOFRs

1/ Seismological Society of America (abstracts), Los Angeles Meeting 1975

AKohl/asb/em 7/22/76

shift at each active fault crossing; these values were discounted to about 60 percent of maximum credible shift for design purposes. The faults and design shift criteria were discussed during the Preliminary Design Review and in meetings between APO staff, MRI, and Woodward-Clyde & Associates in Menlo Park in early 1974. Final Design calculations for the active faults were submitted as follows: Donnelly Dome fault and McGinnis Glacier fault (April 21, 1975), Denali fault (April 23, 1975) and Clearwater Lakes fault Nov. 27 and Dec. 31, 1975). All final designs were submitted to stress specialists in MRI for analysis according to criteria established in volumes 4 (stress) and 8 (active faults) of the Appendices, Criteria and Design Bases. In most respects, the stress analysis proved that the designs meet criteria, and no serious difficulty was encountered with design of the elevated pipeline across three of the faults, other than ability of the pipe supports to withstand lateral loads imposed by the design earthquake, and shoe design at the Denali fault. The buried crossing of Clearwater Lakes fault failed to meet the criteria, as designed.

The Donnelly Dome, Denali, and McGinnis Glacier fault designs have been approved for construction, subject to evaluation of the lateral load pipe supports. Remode of the belowground pipe between Denali and McGinnis Glacier faults to elevated construction has been necessary because of the ice content in the weathered granite. The remode has required redesign of the anchors at the north end of the Denali fault crossing, but is a more favorable design because it removes the vice-like restraint of the buried section between the two faults.

The Clearwater Lakes fault is crossed by a four-mile buried section that consists of a standard buried segment in the north part and a special buried design in the south part. Burial of the north part was done under contractor pressure, at Alyeska's risk without permission of the regulatory agencies, in August 1975. All design change requests for the crossing were returned by APO without action because of serious doubts about the capability of the design to resist the 10 feet of dip shift without damaging the pipe. These doubts were voiced at many meetings with Alyeska, and, finally, Greenbaum of the MRI review staff in Los Angeles, discovered a gross error in the computer application that proved the pipe could not resist the 10 feet of dip shift at the angle designed between the fault trace and the pipeline route.

The design bust left Alyeska several options: (1) Proceed with burial under conditions of Stipulation 3.4.1.2, (2) Reorient the pipeline so that the angle of incidence with the fault would be closer to 90°, and (3) Undertake a program of trenching, surficial mapping, and geophysical work designed to determine whether the fault actually exists, and, if so, to define its location more exactly. After initially electing to bury the pipe under conditions of Stipulation 3.4.1.2, Alyeska management reversed its decision, and contracted the geologic and geophysical study designed by M. C. Metz, Alyeska geologist, to Woodward-Clyde & Associates.

Geologic and geophysical investigations included:

1. Geologic mapping of the Quaternary deposits and surfaces in the vicinity of Clearwater Lakes escarpment and the pipeline.

2. Logging the pipeline trench in the southern part of the fault zone at a scale of 1 inch = 2 feet, collection and dating of radiocarbon samples from the unconsolidated deposits, and sampling for pollen and remnant magnetism.

3. Logging of trenches dug across the Clearwater Lakes escarpment at Clearwater Lake, 1,500 feet west of the Army dock, and across parallel lineaments midway between Clearwater Lake and the pipeline.

4. Geophysical work consisting of gravity, ground magnetic, electromagnetic, and aeromagnetic surveys along traverses about a mile apart.

Results of examination of the southern part of the pipeline trench across the fault zone and of trenches dug across the lineaments between the line and Clearwater Lake showed no evidence for fault movement. The trench across the escarpment at Clearwater Lakes shows conclusively that the escarpment was cut by the Tanana River, and not by a fault. Geophysical work showed that the bedrock topography is a series of buried hills covered by alluvium, and provided no evidence for a fault. These studies were monitored weekly, either in the field or in meetings in Anchorage; opinions of F. R. Weber and T. D. Hamilton of the Survey were obtained, and R. D. Reger of the Alaska Geological Survey was present for discussions in the field. Upon receipt of the two-volume final consultants report, I recommended acceptance by APO of a proposed change in the criteria documents (vol. 8, Criteria and Design Bases) to delete the Clearwater Lakes fault from the list of active faults and have drafted the Notices to Proceed for burial of the pipeline through the former fault crossing.

8.3 <u>Other faults and lineaments</u>

As has been pointed out, seismically active faults without ground breakage exist at the pipeline on the Chena and Salcha Rivers and near the pipeline along Minook Creek. T. R. Magorian, a geophysicist with Ecology and Environment, inc., has been involved in the 1974 discussions of the criteria for active faults and has served several field tours with the MRI surveillance team. He has expressed the opinion that major faults through the Chugach Range that have not been recognized pose threats to the integrity of the pipeline. He called attention to two lineaments that he thought were faults, but provided no records, notes, nor photographs to support his conclusions. Nevertheless, it was necessary to look into each of these supposed faults and settle the issue.

One of these lineaments extends from the mountains east of Brown Creek to Robe Lake, near Valdez, and, according to Magorian, glacial till was believed to have been displaced on either side of the lineament. George Plafker of the Survey was in the field with a helicopter and visited the site of the supposed offset of the till; he concluded that there was no offset and that the lineament was not an active fault. The other lineament thought to be a fault by Magorian extends across the pipeline south of Stuart Creek. Further investigation by MRI and by Alyeska showed that this lineament was also inactive and that quartz veins extended from the wall rock through the fault zone to the wall rock on the other side. Magorian's report of displacement of the Richardson Highway along this lineament during the 1964 earthquake was known to be incorrect before the field check was made.

B.4 Slope stability and liquefaction under earthquake loading

Criteria for slope stability and liquefaction under loading by the contingency plan earthquake are set forth in vol. 3, Criteria and Design Bases and in the Field Design Change Manual. The criteria have been used by Alyeska to evaluate slope stability on a mile-by-mile basis for the entire pipeline. Up to the end of September 1976 MRI and the APO Staff Soils Engineer had not completed their review of the mile-by-mile design.

I was not generally involved in the slope stability discussions between Alyeska and the APO/MRI soils engineers reviewing these criteria and their application. However, I am under the impression that further discussion is needed before final resolution of the problem, which is necessary before APO can accept Alyeska's argument that a Stipulated seismic monitoring system is not necessary because Alyeska has designed the entire pipeline to withstand the contingency plan earthquake. Alyeska's assertion that permafrost retained around the elevated supports by use of heat tubes can prevent damage to the pipeline in the event of thaw-plug failure on slopes deserves further scrutiny.

Problems in slope stability surfaced early in the review of the applications for right-of-way clearing and workpad construction in November 1974. The pipeline crosses a landslide along the south bank of Rock Creek in the Copper River basin; the slide was identified by airphoto interpretation, and later confirmed in a joint field trip with Alyeska consultants. The slide area is underlain by unfrozen ground, and groundwater discharge was noted in springs in an adjacent slide west of the pipeline route. The design called for thermal VSM in the slide area. Alyeska was asked to justify crossing an area of slope instability under provisions of Stipulation 3.5.1; Alyeska performed static and dynamic slope stability analyses, drilled additional test holes, and promised to install one piezometer to measure the pore pressure of the materials. Despite my arguments that Alyeska consider other alignments in this area, APO management in January 1975, after many meetings and exchanges of correspondence, agreed to allow the pipeline to be constructed as designed across the landslide. Alyeska's argument was based on the need for immediate access to the pipeline segment between Rock Creek and Squirrel Creek, which had been delayed 2 1/2 months during these discussions, their impression that the slide area was stable, and the more than 90 days required to re-engineer an alternate route across steep banks that may be subject to landsliding. The final APO letters of approval in February and July 1975 required stability computations using various water tables in unfrozen soil conditions under contingency earthquake loading; four piezometers to be monitored monthly; and, if water table approached an unstable condition, the pipeline should be shut down, the pipe relocated, or the area drained by well points. As of August 1976, the piezometers had not been installed.

8.5 Monitoring fault displacements

The requirement for monitoring fault displacements, as set forth in Stipulation 3.4.2.3, was written at a time when it was unknown whether the fault crossings would be buried or elevated. On October 30, 1974, Alyeska's consultant, Don Tocher (Woodward-Clyde and Associates) presented to APO a plan for monitoring all the fault crossings by installation of a network of bench marks and by annual surveys with electro-optical measuring equipment that would meet the Stipulation at an annual cost of about $100,000. At a meeting between MRI, the State Pipeline Coordinator's Office, R. A. Page of the Survey, and the writer in Menlo Park in February 1975, it was decided that the first order triangulation network would be adequate and less costly than Tocher's plan, and that Alyeska could request a variance to Stipulation 3.4.2.3 to reduce the requirement for accuracy from 0.1 ft in 2 years to 1 ft in 2 years. Later, it was decided that the monitoring requirement for unrestrained elevated fault crossings could be waived by APO, leaving only the buried Clearwater Lakes fault to be monitored. Elimination of the Clearwater Lakes fault by subsequent geologic and geophysical studies leaves essentially no monitoring requirement for fault displacement. As of September 1976, Alyeska had not applied for the waiver of the Stipulation.

8.6 Seismic monitoring system

Stipulation 3.4.1.2 requires a network of ground-motion detectors, rapid-programmed shutdown, inspection, and a special oil-spill contingency plan for hazardous areas where the pipeline cannot be designed to prevent any oil leakage from the effects of the Stipulated earthquakes along the route. The Alyeska Project Description (vols. 1 and 2) promises such a system that will trigger an alarm when the design operating earthquake motion is reached and promises automatic shutdown at the operating earthquake acceleration. Criteria and Design Bases (vol. 3) indicate that the ground motion of the design contingency earthquake is now the basis for design of the pipeline, pump stations, and terminal. Alyeska engineers contend that a stipulated monitoring system is not required, but for their own protection they will install a monitoring system to be provided under contract with the Sundstrand Company for about $700,000. Under terms of the contract, only the first two or three units of the system will be installed before planned startup of the oil line in mid 1977; thus, timely startup depends on relief from the stipulated requirement for an operating seismic monitoring system. This problem had not been resolved as of late September 1976. With advice from H. W. Coulter and R. A. Page of the Survey, I have recommended strongly to the Authorized Officer and others in APO that the stipulation requirement be kept, mainly to be sure that a monitoring system will be used during the life of the pipeline.

Alyeska plans to install a digital strong-motion accelerograph with some computational ability and with communication capability at Pump Stations 1, 4, 5-12, and at the terminal. The accelerograph will continuously monitor ground motions, and on detection of motions exceeding a predetermined level, will initiate recording of the motions, including approximately 10 seconds of pre-event data. Recording of data will be terminated 30 seconds after the last motions exceeding the predetermined level. Data from each site will be processed locally on a real-time basis to obtain key parameters for an earthquake event. Peak acceleration and velocity alarms will be transmitted from each instrument to Valdez over the Backbone Communication System within 10 minutes after an earthquake. A voice-grade seismic channel (microwave) with satellite backup has been selected for transmission of post-earthquake data. The information will be transmitted to the computer at the control building at the Valdez terminal. Page, in his review of the plan, points out that reliable earthquake locations cannot be determined from a linear array of seismic detectors and that a computer-based, real-time earthquake detection and location system to monitor earthquakes above Richter magnitude 7.5 is necessary to satisfy the intent of the Stipulations. From the location and magnitude of an earthquake, the computer could estimate levels of ground motion along the pipeline and the likelihood of surface faulting. The outcome of the discussions on the monitoring system hopefully will be based on my recommendations and reviews and on the reviews of R. A. Page, but the decision has not yet been made.

9.0 Vertical Support Member (VSM) design

A long series of meetings between the State and Federal pipeline offices and Alyeska on the design criteria for Vertical Support Members (VSM) resulted in approval of the design on December 12, 1974, by the State Pipeline Coordinator's Office and disapproval on December 3, 1974, by Alaska Pipeline Office until results of certain tests could confirm the design. Topics under discussion included: design temperature, VSM bearing capacity, soil and slurry shear strength, adfreeze bond strength, effect of corrugations on VSM bearing capacity, soil salinity and slurry-water purity, allowable creep rate and total VSM displacement, and thermodynamic justification of design criteria. Fred Crory of Cold Regions Research and Engineering Laboratory, U. S. Army, participated in the discussions and review and has followed this problem throughout the project.

As a result of these meetings, Alyeska and Alaska Pipeline Office agreed to allow installation of VSMs at Alyeska's risk, subject to the following conditions:

1. Pending completion of the below-mentioned test program, Notices to Proceed for installation of thermal VSMs will be based on current Alyeska design criteria, supplemented by the requirement that pile penetration in permafrost be checked and adjusted when necessary to give maximum shear stress at the pile-slurry interface of 800 psf for design-operating pile loads. Design will take into account two feet of skin melt.

2. Thermal VSMs will be used in all deep frozen profiles south of the Brooks Range divide (Atigun Pass).

3. End plates will be seal welded to the bottom of all thermal VSMs.

4. Alyeska will conduct laboratory pile load tests to confirm failure

modes and load capacities of corrugated VSMs installed in a sand slurry of design specification and temperature. Testing will be completed in 3 months (Univ. of Illinois).

5. Alyeska will conduct field load tests of 3 VSM each in dense gravel, Copper River Basin clay, and low density Fairbanks silt. Testing will be completed in 6 months.

6. Scope of procedures of the test program agreed on by APO and Alyeska staffs. Specific procedures and modifications in the test procedures shall be agreed on by the APO and Alyeska staffs.

Discussions of the Vertical Support Member (VSM) design continued intermittently from late 1974 to early 1976, when both parties held intensive discussions, the results of which are summarized in the pages that follow in Staff Soils Engineer's April 8, 1976 memorandum for the record. As of September 30, the discussions were being continued in response to Alyeska's August 20th request for full and unconditional approval of the design, and the designs were finally approved in October or November.

(B-33A follows)

COPY

Files

April 8, 1976
In reply refer to:
P001.0801, .1813
.0203

Soils Engineer

April 2, 1976 APSC-APO Meeting on Unresolved VSM Criteria

A. A. list of attendees is attached.

B. Hal Peyton introduced the subject and discussed the design of the aboveground system indicating an overall high margin of safety with respect to pipe rupture. He then asked Jim Maple to address the stress aspects of the aboveground system.

C. Jim Maple pointed out that in the real world VSM failure generally cannot cause pipe rupture. Settlement of VSM would be obvious to O & M personnel long before pipe stresses exceeded sustained operating limits as per pipeline code and regular maintenance could correct the problem.

D. John Wheeler, EPR, treated the thermal aspects of the VSM system. He said that all analyses had been completed including verification of the thermal model with the Chena Valve Test site data as well as calculations for the as-built (shorter) piles. Also, calculations had been completed for short piles in unsaturated soils. He elaborated on three remaining concerns.

1. Unfrozen moisture content input to the thermal model for all soils is based on the Anderson-Tice equation which has been shown by Crory not to be applicable to naturally occurring permafrost soils. CRREL is now doing research on undisturbed soils to develop a realistic method of predicting the variation of unfrozen moisture content with temperature. This research is to be completed in mid-June, 1976.

2. He indicated that their calculations show that the design can accommodate up to 1°F freezing point depression but that saline pore water which would have significant freezing point depression would be a problem particularly in coarser grained soils as temperatures are more critical. APO pointed out that the slurry sand used in the University of Illinois tests had a 0.17°C freezing point depression.

3. Ground water flow - the state of the art is poor and analytical tools are not developed. Site conditions are hard to

model. They cannot demonstrate that ground water flow will not be a problem but they think that it is significant only in originally unfrozen soils. This would have to be handled by O & M if a problem develops.

4. Monitoring at the Chena Hot Spring Valve Test Site will be continued for several years. Subsurface temperatures on mainline VSM in other soil types and locations will be monitored during the O & M phase. (39 locations have been identified at this time for originally frozen soils--other locations and conditions will also be monitored as well.)

E. E. W. Black (WCC) addressed the geotechnical aspects of the design. He saw the problem of the aboveground pipeline as being of a maintenance nature rather than of rupture and an oil spill, but posed the question of what is an acceptable level of VSM failure for O & M.

The field work on the pile load tests in the three soil types has been completed and documentation will be submitted to APO soon.

He has drawn the following conclusions from the test data:

1. The Alyeska design is supported by the test data.

2. In no case did plunging failure occur with corrugated VSM unlike the behavior of smooth VSM.

3. If the load is backed off, the load tends to stabilize but they have not held the load sufficiently long to confirm that creep ceases.

4. Results for end-bearing are indecisive probably because of lift-off due to corrugations and floating of the VSM. Mobilization of end-bearing is feasible but will require substantial settlement.

F. H. Peyton made the following comments regarding APO's list of unresolved VSM criteria (the numbering and lettering is as on the attached list).

1. Efficacy of thermal VSM

   a. Thermal model - there will be a match of the thermal model output with the test data from the Chena Hot Springs Valve Test Site using site specific data. The values of the in-put variables will be compared to the design values and a catalogue will be made of conservatisms and sensitivities.

b. Thermal monitoring of mainline VSM, etc. - The procedure for monitoring mainline VSM temperatures with design temperatures will be outlined. The report will include the O & M responsibility for observation and replacement of heat pipes.

2. Use of thermal VSM in the following:

a. In frozen soils with less than 50% passing #200 sieve.

c. In profiles with 13 feet of frozen clay or silt over frozen clean sands and gravels.

d. In mixed frozen - thawed profiles.

e. With insulation in or below the work pad in warm permafrost.

The above will be affected by the justification of the thermal model in 1.a. above as well as by assumptions regarding unfrozen water content. Alyeska intends to support unfrozen water content values by specific surface area calculations (CRREL test data should be available by mid-June and should be used as a check). Alyeska will also analyze the Tice-Anderson data and show the relation to design particularly for Alaska silts.

b. In thawed silt or clay soils:

The piles which have been placed in unfrozen soil and in which heat pipes have not been placed will not support the hydrotest nor the oil load. These will not be treated in the forthcoming report but will be dealt with separately at a later date.

f. With drainage (erosion channels) close by:

Ditch depth will be controlled by Alyeska as the VSM cannot tolerate a deep ditch close by.

3. Long-term shear/adfreeze strength for vertical loads.

a. Slurry at 30.0 and 31.5°F.

b. Three soil types at 31.5°F.

Aleska will submit documentation on all these tests.

c. Massive Ice.

There are problems in verifying the criteria for vertical and lateral loads. APO is awaiting additional data from CRRELL but the criteria may prove to be beyond proof and VSM in massive ice will require strict O & M observation.

d. Special design

No criteria have been submitted but Alyeska will deal with these in a DCR rather than in this proposed report.

4. Lateral load criteria

APO will review Alyeska's report using CRREL data which haven't been transmitted as yet. Alyeska will catalogue the magnitude and durations of loading so as to assist APO in their review.

5. VSM grout strength

This will continue to be handled on a DCR basis.

6. Thawed soil-grout interface friction values (Table 3.0.5 in FDCM, Vol. 1)

7. Active layer depths (Table 3.0.6 in FDCM, Vol. 1)

Both of the above will be handled in the review of the FDCM, Vol. 1

8. Freezing point depression

This was discussed earlier by John Wheeler who stated that he would like to see the CRREL freezing point depression data on the slurry used in the University of Illinois tests.

9. Corrosion of grout-soil interface

Apparently this question has been resolved but geotechnical personnel in APO/MRI were unaware of the outcome.

10. Freezeback - hydro test and oil

Alyeska does not intend to deal with this in the report but APO remains concerned as the effects of movement by VSM in partially frozen slurry may not be comparable to similar movements in a fully frozen slurry. Alyeska intends to do a survey prior to hydrotest and another immediately after so as to detect any movement of the VSM due to the hydrotest.

11. Split VSM

12. Field Design Change Manual, Vol. 1.

13. Specification 2.20.

    Alyeska will deal with these by DCR rather than in the report.

14. Becker Thermal - Frozen Granular Soils with more than 10% passing #200 sieve.

    Alyeska hopes to resolve this dispute by validating their thermal model and unfrozen water content assumptions.

Shortening of heat tubes

This item was discussed although not on the APO list. Alyeska stated that they had field data from the Chena Hot Springs Valve Test Site which would substantiate the proposed shortening of the heat tubes.

Ice formation on the outside of the slurry, grout, etc.

Although not on the APO list, this item was also discussed. Alyeska stated that they could only watch slurry and grout temperatures and keep them as low as possible to minimize the problem.

/s/

Attachment

EEllis:nm 4/8/76

cc: w/attachments
MRI files
Ralph Isaacs

April 2, 1976

VSM MEETING

Name	Organization
Bob Neukirchner	Alyeska
Chris Whorton	Alyeska
John Wheeler	EPR - Alyeska
Chris Heuer	Alyeska
Peter DeMay	Alyeska
Hal Peyton	Alyeska
Al Liguori	Alyeska
W. T. Black	WCC
J. A. Maple	Alyeska
Richard S. Wolf	MRI
Ralph M. Isaacs	MRI
Earl T. Ellis	APO
M. J. Turner	APO
Arlan H. Kohl	APO

4/1/76

UNRESOLVED VSM CRITERIA

1. Efficacy of Thermal VSM

    a. Thermal analysis is state of the art -- Observation of soils temperatures at Chena Hot Springs Valve Site to help verify theory for silt soils. Thermal monitoring on main line VSM in other soil types and locations to help verify Thermal Model.

2. Use of Thermal VSM in the following:

    a. In frozen soils with less than 50% passing #200 sieve. (Unfrozen moisture content -- CRREL doing research to be completed by mid-June 1976.)

    b. In thawed silt or clay soils.

    c. In profiles with 13 feet of frozen dlay or silt over frozen clean sands and gravels.

    d. In mixed frozen -- thawed profiles.

    e. With insultation in or below the work pad in warm permafrost.

    f. With drainage close by.

3. Long-Term Shear/Adfreeze Strengths for Vertical Loads

    a. Slurry at 30.0 and 31.5°F (Illinois and

    b. Three soil types at 31.5°F field tests)

    c. Massive ice.

    d. Special Designs:

        (1) Grouted Thermal

        (2) Special Design Thermal

        (3) Friction Thermal.

4. Lateral Load Criteria

    a. Frozen Soils (We are awaiting

    b. Massive Ice. information from CRREL)

5. VSM Grout Strength

6. Thawed Soil-Steel Skin Friction

7. Active Layer Depths (Thermal VSM in Cold Permafrost)

8. Freezing Point Depression

9. Corrosion of Grout-Soil Interface

10. Freezeback - Hydro Test and Oil

11. Split VSM

12. Field Design Change Manual

13. Specification 2.20

14. Becker Thermal -- Frozen Granular Soils with More Than 10% Passing #200 Sieve.

    Note that performance of thermal VSM is important not only for direct pipeline support but also for slope stability.

    Revegetation of the work pad may be essential to improve the performance of Thermal VSM.

To avoid any potentially damaging settlement produced by hydrotest loading, thermal VSM placed in initially frozen soils should not be loaded until the heat tubes have had time to lower the temperature of the slurry and soil around the slurry to less than 32°F. Hydrotesting should be delayed until the heat tubes have frozen the ground or until a sufficient depth of active layer has frozen to help support the load. If hydrotesting must be done before these conditions were satisfied, APO asked Alyeska to make sure that each bent is carrying its share of the load and to survey each VSM to an accuracy of 0.1 inch before and after hydrotesting. Alyeska was to develop a contingency plan to remedy those VSMs that had measurable settlement. Because of the approach of freezing temperatures, Alyeska was allowed to perform hydrotests, and some of the VSMs did settle appreciably so that remedial measures will be necessary. The alternatives available to maintain construction schedules were allowing winter hydrotests with diesel fuel, crude oil, or methanol, which might lead to undesirable environmental consequences in case of a break in the line.

10.0 Buried construction

10.1 Problems

A number of special construction problems arose in laying pipe in the trench. In general, the trench was opened more rapidly than the pipe could be laid, and it was common to have more than one mile of open ditch ahead of the pipelaying spread. This situation alarmed big game biologists of JFWAT, but no moose or caribou were caught in the open trenches.

Sloughing of the banks was a common problem in these open trenches.

Stones in the ditch bottom or on the sides were not always cleaned out before pipelaying. Even though bedding material was added before placing the pipe, some of the stones were left in a position where they could rub against the pipe, damaging the coating and taping. Corrosion of the pipe from this damage is a potential cause of leaks in the pipeline over the years.

Wet ditch required use of weights, and it was impossible to detect stones or to assure that the bedding material was spread evenly to specified thickness and that it provided uniform support to the pipe. In many dry ditches the pipe did not fit the ditch and did not rest on the bedding material. In such cases the padding material was not always poked under the pipe to give the uniform support required by the specifications. In a few cases, water ponded on the uphill side of the trench by the spoil pile was allowed to flow into the trench, bringing with it mud and rocks that lodged close to the sides and bottom of the pipe. These flows also washed out bedding material. Most of these problems came about by failure of the contractors to build according to specifications and from an inadequate system of quality control. With only three people per 150-mile pipeline spread, APO and MRI obviously could not catch all violations of the specifications. Even when such violations were detected and remedial work requested, the Government inspection team had no idea how much of the adjacent freshly-buried pipe may have been built in violation of specifications. The gross nature of some of the out-of-specification work leads me to suspect that much substandard work went undetected.

Constant pressure was applied by Alyeska to vary the specifications for gradation of bedding and padding materials and to substitute crushed stone or crushed sand and gravel for specified fine gravel and sand, under pressure from the contractors. Perhaps with more advance planning, geologic studies should have been used to locate suitable sources of bedding and padding material at the time the materials sites were chosen. Choice of many of these sites was originally made for the materials needed for construction of the haul road and work pad, requiring a generally coarser material than needed for bedding and padding.

10.2 Short buried animal crossings in elevated pipeline sections

Early in the design review the need for providing crossings for large migratory animals was recognized, especially in the long elevated sections of the line between Galbraith Lake and Happy Valley. In many other areas migration routes for large animals coincided with poor soil conditions that precluded use of buried mode. A typical special sag-bend design for a buried animal crossing is located at a point on the elevated line where horizontal pipe shift is near zero. It is 300 feet long and has a 60- to 70-ft buried section at its center. The special designs can be used whenever predicted thaw settlement based on borings at the crossing does not exceed two feet. Special analysis and design are required for greater thaw settlement. Stress analysis in the design of the crossing must account for increased loads on the aboveground supports immediately adjacent to the crossing and for increases in the effective stress in belowground sections.

10.3 Refrigerated burial

Refrigerated burial is being used in areas of ice-rich fine-grained materials at the Glenn Highway crossing and in a section east and north of the Gulkana River bridge. Criteria questions are mostly resolved, and monitoring of the effectiveness of the system will be required in limited areas for the early years of operation. The monitoring is a check on the design to verify that the operation of the system can be checked by temperature measurements of the outgoing and incoming brine solution.

10.4 Deep burial on thaw stable gravel or bedrock beneath ice-rich silt

A part of Stipulation 3.3.1 states that material above the centerline of the pipe must be stable -- that is, the overlying material must not be so rich in ice that serious terrain disruption occurs. The decisions to issue permits for variance to the Stipulation for burial of the pipe under these conditions have required special care not to allow burial beneath significant amounts of ice-rich silt on steep slopes, particularly in Pipeline Sections 3 and 4 between Fairbanks and Coldfoot. In areas of low relief, the problem was judged on the amount of anticipated thaw settlement and the need for maintenance against the disadvantages of numerous short above-ground sections in an otherwise buried line. In some valleys special designs have been worked out by which the trench is overexcavated to thaw stable material, widened as necessary to provide room for a stable plug of gravel backfill, and the pipe buried at normal depth. Monitoring of some of these sections will check the efficiency of the design. Considerations in granting permits include the character of the soil and its ice content, terrain, and pipe-stress.

11.0 Atigun Pass

Atigun Pass, 4,738 feet above sea level, is the highest point on the pipeline. It lies at the continental divide in the Brooks Range between the Chandalar and Atigun River drainage systems. Aside from its scenic values and game considerations, the numerous avalanches and slush flows on the south side of the summit have dictated that the pipeline be buried throughout the pass (Stations 53+82 to 253+74AH, Alignment Sheet 110). Discussion of design review problems in Atigun Pass is presented in chronological order, and the results of the more than 80 meetings between APO and Alyeska in the office and in the field are highlighted.

Early in the design of the pipeline Alyeska considered driving a tunnel through the pass, but the proposal was discarded in favor of a conventionally buried pipeline over the summit. Now, after nearly two years of designing and redesigning the overland crossing, a tunnel looks more attractive, but the time remaining before scheduled commissioning of the line does not permit the test work, contracting, mobilization of equipment, and driving of the tunnel. Such a tunnel would in all likelihood be easy to drive through the shale that lies beneath sandstone and conglomerate of the upper slopes and summit. A pipeline tunnel of about the same length was driven through slate and argillite between Portage and Whittier in about a year.

The Preliminary Design Drawings for the overland route showed an alignment that was distorted by elevation during photogrammetric compilation, and was shown to cross rock glaciers north of the summit, pass beneath haul road fill, and was otherwise incorrectly located. A letter

from APO to Alyeska in October 1974 called attention to the inadequacy of the design drawings and lack of test borings to justify conventional burial in an area where highway excavations had revealed excess ice in unconsolidated deposits and marginal amounts of ice in bedrock. Meetings were held with Alyeska, and a 10-hole test drilling program proposed by the Alyeska geotechnical staff was rein-
stated, and the alignment correctly plotted on aerial photographs at a scale of 1 inch = 500 feet. The pipe centerline was moved from beneath the road fill and was placed at least 100 feet from the toe of the nearest rock glacier.

Based on these early meetings in the winter of 1974-75 and spring of 1975, construction of work pad was authorized to facilitate the drilling program, which required use of large rigs. The work pad up the brook on the south side of the pass was limited in width and designed to avoid cuts in talus cones of bordering slopes. Pad construction was authorized through the summit to the upper part of the north slope, but was withheld on steeper parts of the north slope. Blasting at the summit was held to a minimum, although much was done in connection with road construction. The pioneer work pad on the south side of the pass was washed out during the 1975 spring snow melt, the sediment collecting in a trap constructed for that purpose in Material Site 110-1 at the bottom of the hill. The pad was constructed on verbal assurance from Alyeska that no other route than that along the stream was possible for the pipeline.

The 1974-75 winter test drilling program consisted of an initial 10 locations, but was supplemented later by holes drilled as needed to define ice-rich areas. Northward from the summit test holes indicated mostly shallow bedrock, with local areas of thick ice-rich till (from Station 196+00 to 212+00) where ice masses as thick as 5 feet were noted near the surface. The upper road crossing on the original alignment was drilled at least 48 feet to rock, with an ice content of as much as 30 percent in some zones in the till. A problem was foreseen in anchoring the casing to carry the pipe beneath the road on such a steep slope, and extensive cutting would have been needed on the uphill side of the road to provide proper grade. The slope below the road crossing was too steep for drilling equipment, and APO was unwilling to allow pad construction for the use of large drill rigs. However, a hole on the alignment at the base of the hill reached bedrock at 42 feet. The material overlying bedrock was largely ice, and the estimated thaw settlement was 25 feet. In an effort to keep to the original alignment, Alyeska considered excavating to 42 feet, insulating the trench walls, and backfilling with shot rock or rubble to provide stability for the buried pipe. This plan proved unworkable, and additional test work nearby was unsuccessful in an effort to avoid the ice by a minor relocation of the line. The ice-rich area proved extensive, and as much as 47 feet of ice was found. A realignment was obviously necessary, and meetings were held with Alyeska engineering in Anchorage and with field engineers at Atigun Camp on the proposed reroutes. A more gentle slope to the west of the original alignment was selected downhill from the broad curve in the haul road. Test drilling with air-track equipment proved that bedrock beneath the steep slope is shallow, except at the upper road crossing where till is about 60 feet thick. Thaw settlement in the till is close to the maximum allowed by

Alyeska criteria (1 foot), but Alyeska designers believe that some of the settlement will be taken up by excavation and backfill and by resistance of the casing beneath the road to differential settlement. Test drilling from the upper road crossing along the reroute southward to the old alignment revealed relatively shallow bedrock with a few 30 to 35-ft deep pockets of frozen till having a marginal ice content. The old alignment between Station 196+00 and 212+00 had to have a special design provided to handle the undesireable amount of ice in the till.

The 1974-75 test drilling program in the valley on the south side of the summit found that bedrock depth exceeds 96 feet in places and that as much as 30 feet of ice-rich material (Station 140+00 to 142+00) could produce thaw settlement of between 2 and 4.5 feet.

From July through September 1975 Alyeska engineering worked on a special design using an insulated trench based, in part, on the animal crossing design, to handle the thaw settlement problem on the south side of the summit. Additional test holes were drilled to define the area for which the special design was needed. At several meetings between APO staff and Alyeska designers, the concept of an insulated trench proved unworkable because no way could be found to handle the convective heat transfer by ground water in the valley bottom, nor any way to divert the stream. The attempts to design an insulated trench were abandoned in late September 1975.

During the fall and late winter of 1975-76 Alyeska's field engineers conducted additional test drilling and submitted a design in early 1976 for side-hill construction of the line along the lower end of talus cones bordering the stream south of the summit between Stations 113+00 and

156+00, the area defined as ice-rich. The route of the proposed redesign and relocation was drilled out with air-track equipment, and some ice layers were located in the talus deposits. The advantage of the proposed redesign was simplicity in construction by cut and cover methods and elimination of much of the water problems to be encountered in the valley bottom route. The redesign and relocation was submitted as a Design Change Request in March 1976 along with other Design Change Requests for changes in depth of burial to account for the position of bedrock, for relocation of the line in the bowl area just south of the summit to avoid ice-rich glaciolacustrine clay, and for the relocation of the line between Station 212+00 and the lower road crossings north of the summit. Review of these proposals showed that all burial, except that in or on bedrock would require a variance to Stipulation 3.3.1 because of excess silt in the frozen unconsolidated deposits. An area between Stations 196+00 and 212+00 north of the summit and another between Stations 113+00 and 156+00 on the sidehill reroute south of the summit would require a special insulated design. All of the revised burial depths and relocations proposed were combined in Design Change Request DCR #5-64 submitted in Late March 1976. After much discussion and several field trips the relocation was approved in July, the section between Stations 113+00 and 156+00 being moved closer to the stream to avoid excessive cuts in the talus. A program of test pitting and test drilling to confirm soil conditions was required as a basis for the variance to Stipulation 3.3.1 wherever the pipe was not to be laid in bedrock.

A special design for insulating the pipe in ice-rich deposits between Stations 196+00 to 212+00 and 113+00 and 156+00 was submitted in late March 1976 as Design Change Request DCR ES-62. The initial submittal consisted of a series of drawings showing alternative ways that board stock insulation could be placed around the pipe and a discussion of the thermal logic of such a design based on work done by Esso Production Research for Alyeska on the buried animal crossing design. In mid April, after much discussion, the design change request was amended by addition of drawings of an insulated box constructed of panels of Dow HD-1623 polystyrene, 21 inches thick, factory-fabricated from 3.5- and 4.2-inch thick board stock. The interlocking panels are 8 feet high and 9 feet long. The box, at first, was to be filled with sand around the pipe and the panels were to be glued together by Mastic II. In presenting this revised design, Alyeska stated that to meet construction schedules approval must be given within three days to place the order for fabrication at the factory. APO Technical staff rejected the box concept, and favored use of curved insulation that fit the pipe to be made up so that sections would interlock and could be strapped on the pipe. The insulation would have to be protected by rock shield. The Staff was overruled by APO management because Alyeska has the option to design the pipeline their way and because Alyeska stated that the curved insulation could not be fabricated in time to meet construction schedules. The letter approving the insulated box concept carried the notation that the box be watertight to prevent convective heat transfer by ground water.

The insulated box design evolved further during a series of meetings with the change from a fill of sand to a fill of grout, from two zinc anodes to four magnesium anodes, by addition of plywood sheathing on the walls and top to protect the insulation, and by addition of a 12-inch concrete foundation 12 feet wide to which metal straps are bolted to hold the plywood sheathing in place.

The conductive heat flow model of the insulated box design shows that the design is marginal and that after 30 years of operation conductive heat flow will create a small thaw bulb beneath the box. This means that any convective heat transfer from the pipe or warm grout caused by ground water circulating through cracks in the insulation may affect the thermal regime of the ground significantly. It requires also, that effective ditch plugs be installed to prevent ground water heated by uninsulated pipe from moving below the insulated box. In order to dissipate heat to the surface, the overburden or cover of the insulated box is limited to 4 or 5 feet. And, only a limited amount of ditch can be left open ahead of the box construction under summer temperature conditions because it is necessary to prevent thaw of permafrost under the box. This latter condition was not followed rigorously during construction of the box in August through November 1976 because air temperature was generally low; nevertheless, ponded or flowing water in the ditch and above-freezing temperature doubtless caused some thaw of the permafrost.

Special requirements for protection by riprap and burial beneath thalweg depth of the stream on the south side of the summit (Station 113+00 to 156+00) were not settled until early August 1976.

Construction of the pipeline through Atigun Pass was slightly more than 50 percent complete when I left the job in late September 1976. I learned on November 9th that the work is now complete except for construction of the box between Stations 113+00 and 156+00. Hydrotesting of this part of the line was (in September) scheduled for May 28, 1977.

The whole sequence, sketched without addition of all the details, illustrates the difficulties of attempting piecemeal design, the effect on construction schedules of inadequate design data (test holes), communication problems, and of letting resolution of all problems go until they reach crisis dimensions. Many involved on both sides of the project wish a tunnel had been used through this difficult section; in fact, Alyeska's field engineers sent such a request to their engineering office in Anchorage in early 1976, such was their frustration with the design finally adopted.

12.0 Water-supply problems

Provision of a safe and adequate water supply for the temporary construction camps, permanent pump stations and terminal is largely outside the Stipulations, yet it is an important part of a project of this magnitude. Because of my past experience in this kind of work, I was called on to discuss water-supply problems with Alyeska. I met with Alyeska officials in charge of pump stations in late 1974 and recommended exploration for ground water at each of the stations. For a small complement of men, a ground-water supply is ideal because it eliminates the need for expensive heated water trucks, highly-paid drivers, and keeping surface-water intakes open. Pump station construction camps require a continuous flow of about 23 gallons per minute (gpm), and the permanent station camps require only 5 to 10 gpm -- well within the range of a bedrock well. The larger pipeline construction camps required a continuous flow of about 50 gpm. Alyeska had found that most of these camps, located along water bodies, could be provided with ground-water supplies. However, the pump station drilling program was more difficult because the stations are commonly on hilltops. Some failures to develop a satisfactory supply from pump station wells were caused by lack of proper supervision of the work or by poor selection of drillers. The water-supply problem north of the Brooks Range is very complicated, and hardly the place to experiment with an untested consultant, as was the case. Alyeska should have had a single authority for water-supply work within its organization, staffed by skilled people, who could supervise the drilling and developemnt of wells. The attached table shows that they had a reasonable degree of success, even without the proper skills and supervision.

Water sources at camps, pump stations and terminal

Terminal, camp, or pump station (from south to north along line)	Type of supply	Adequacy	Problems
Valdez terminal	Gallery, Allison Creek	Adequate	None
Sheep Creek camp	Well (?)	Adequate	None known
Pump Station 12	Well	Adequate	None
Tonsina camp	Wells	Adequate	None
Glennallen camp	Well	Adequate	High salinity, hardness
Pump Station 11	Well planned	-	Station not built
Sourdough camp (abandoned)	Well	Not adequate	Saline water
Isabel camp	Well	Adequate	None known
Pump Station 10	Well	Adequate	None
Pump Station 9	Well	Adequate	None
Delta camp	Well	Adequate	None
Pump Station 8	Wells/haul water	No water in wells	Too close to sewage lagoon
Fort Wainwright	Military wells	Adequate	None
Pump Station 7	Unknown	-	Station not built
Livengood camp	Well	Adequate	None
Pump Station 6	Wells (3 drilled)/haul	Not adequate supply	5 gals./minute at best
Fivemile camp	Wells (?)	Unknown	None known
Old Man Camp	Wells	Adequate	Long supply line
Prospect Creek camp	Wells	Adequate	Two of 3 wells contaminates by oil spill
Pump Station 5	Well/haul water	No water	Silty materials
Coldfoot camp	Well	Adequate	None
Dietrich camp	Wells	Adequate	None
Chandalar camp	Bedrock well/gallery	Inadequate	Limited supply late winter
Atigun camp	Bedrock well/gallery	Inadequate	Limited supply late winter
Pump Station 4	Well (Tea Lake)	Inadequate	Siltation; long supply line
Galbraith camp	Wells	Adequate	None
Toolik camp	Unknown	-	-
Happy Valley camp	Gallery	Inadequate	Limited supply late winter
Pump Station 3	Gallery	Unknown	-
Pump Station 2	Gallery proposed	Unknown	-
Franklin Bluffs camp	Gallery	Unknown	-
Pump Station 1	Haul from lake	Unknown	-

13.0 Work-pad design

The preliminary design had an elaborate system of work pad position and thickness to accomodate the various configurations of the pipe and the season at which construction was planned. In general, an insulated pad was planned north of the Brooks Range divide, and a gravel pad as thick as 6 feet south of the divide. It was recognized that no practicable thickness of work-pad material south of the Brooks Range could eliminate disturbance of the thermal regime of warm permafrost beneath the pad. During the final design review, the construction schedule became completely disorganized from that originally planned, and redesign of individual segments of work-pad became hopeless -- impossible to review in the office, and difficult to apply in the field. By arrangement with APO, Alyeska provided a tabulation of work-pad thickness based on winter construction, to which additional thickness of material could be added as needed to provide an adequate working surface over soft ground, ice-rich materials, and other sensitive areas. Decisions on pad thickness were delegated to the field.

The criteria question on the effect of non-insulated work pad on the thermal regime in underlying materials has never been satisfactorily resolved. Without doubt, there will be serious instability and failure of the pad and underlying thaw bulb, Alyeska believes failure of the pad and thaw bulb beneath it will not disturb the elevated supports and expects that maintenance of permafrost around piling equipped with heat tubes will tend to prevent failure on slopes. The effect of increased seasonal thaw depth beneath the pad on piling design is supposed to be accounted for in the design.

13.1 Snow pad

Alaska Pipeline Office has encouraged the use of snow pad, and, in its Notices to Proceed for right-of-way clearing and work pad construction, dictated use of snow pad to supplement a narrow gravel pad between Willow Creek and Klutina River (Copper River Basin), use of a full snow pad across sensitive ice-rich soils near Globe Creek, and a full snow pad for seven miles between Toolik and Slope Mountain. The requirements of the Notice to Proceed were ignored between Willow Creek and Klutina River because, even though pad construction was done in winter, the VSM and pipe construction could not be scheduled for the winter season. Full snow pad was used at Globe Creek and for the seven miles between Toolik and Slope Mountain, but not without protest. Snow pad is being used in construction of the fuel gas line between Pump Stations 1 and 4. The results of this experience will have some bearing on proposals for future pipelines.

In theory, use of snow pad is a good idea. However, from a practical construction standpoint, its use places severe limitations on scheduling and deployment of equipment. For example, the elevated pipeline is constructed by many different construction "spreads", each appearing in sequence -- pad construction; drills to place VSM holes; crews installing VSMs; laying or stringing the pipe; welding the pipe; placing the pipe on cross beams; adjusting the cross beam and pipe; placing the insulation; and many different inspection operations. In normal construction practice these activities are carried on over a period of many months. To compress all these activities into the snow pad season restricts the freedom which construction contractors and planners like to have to manipulate the different spreads efficiently.

During the 1975-76 winter construction season, experience showed that too little snow accumulates to make a satisfactory pad in the Arctic and that the effects of wind on the snow cover are hard to deal with.

The work pad problem was discussed in a meeting held by Water Resources Division of the Survey and Arctic Gas, which is thinking about using ice pads for construction from Prudhoe Bay to the Alaska-Canada border in the Arctic Coastal Plain. Success in construction of snow and ice pads depends on having the right mental attitude, the proper procedures, and the right equipment for their construction. Alyeska was not prepared to use this type of pad.

13.2 Work-pad cuts in ice-rich material

Examination of applications for Notice to Proceed for construction of the work-pad and clearing of the right-of-way involved APO and Alyeska in many discussions on erosion control and thermal erosion of ice-rich cuts. At first, the major ice-rich cuts, as determined from the logs of test holes and photointerpretation of the pipeline route, were identified and were windows or holds in the Notices to Proceed until a satisfactory erosion-control plan was submitted. The large number of windows in the Noctices to Proceed complicated the paperwork and made it difficult for the contractor to work. Alaska Pipeline Office worked with Alyeska to develop a master list of ice-rich cuts that would be handled by procedures to control thermal erosion and reduce siltation. This list and the procedures were added to the Erosion Control Manual (vol. 4, Field Design Change Manual).

Experience on the Livengood to Yukon River road showed Alyeska that vertical cuts could be made in ice and ice-rich material and that they would self stabilize, provided adequate maintenance work was done to keep the road smooth and to eliminate siltation from the melting ice in the cuts. APO did not necessarily agree with Alyeska's findings, and to minimize the amount of cutting in ice-rich materials, required overlay construction wherever possible, usually on all cross slopes up to 20 percent. Even this type of construction is not without problems, for the drainage back of the overlay pad passing through culverts has begun to cut thermally widened and deepened trenches downstream from the haul road in some places. Whichever method of construction is used in ice-rich areas, the long-term outlook for maintenance requirements and environmental damage is not bright.

14.0 <u>Fuel gas line</u>

The power system for Pump Stations 1 through 4 is designed to use natural gas as well as fuel oil. Natural gas is to be pumped through a 10- and 8-inch supply line as far south as Pump Station 4 near Galbraith Lake. Later, if either the El Paso or Northwest Gas proposals for a major gas line along the route of the oil line is approved, taps can be installed to supply each pump station, and the fuel gas line abandoned.

The fuel gas line was routed along either the haul road or the oil line work pad, the final route being chosen only after considerable argument between APO management, a divided APO Staff, Alyeska, and the Alaska Department of Highways. The line is to operate at ambient temperature. The easiest solution would have been to lay the line on the surface, but the quality of the steel was such that it could not withstand cold winter temperature.

Construction of the line began early in the winter of 1975-76 and was scheduled for completion in one winter season. As it turned out, the winter's work was plagued by equipment problems in finding the right tools to dig the narrow trench two to three feet deep. Various types of rock saws and trenching machines were used, and blasting was attempted in some areas. The blasting was unsatisfactory because it created a broad zone of tundra disturbance and hurled debris onto the tundra away from the trench.

Gullying and thawing took place along the blasted ditch during the summer of 1976, and will require much maintenance expense in future years. As a result of these problems only half the job was completed in 1976-76 winter at a cost reportedly eight times that budgeted. Completion of the line in the winter of 1976-77 is being given to a new contractor.

15.0 Lacustrine silt, Dietrich and Middle Fork Koyukuk Rivers

Silt, sandy silt, fine sand, and clayey silt form the bottom set beds of glaciolacustrine deposits behind moraines or bedrock dams in the Dietrich and Middle Fork Koyukuk River valleys. These deposits locally are more than 150 feet thick. Along the trunk valleys they are covered by sand and gravel alluvium having a thickness approximately that of the depth of scour. The cover of coarse alluvium is thicker along tributary streams where alluvial fans have been deposited at the valley margin. Locally deltas consisting of sandy gravel and sand are preserved at the valley margin.

From a practical point of view, it was recognized during design review that the shallow fine-grained deposits posed a problem in or near the rivers, where permafrost is discontinuous or is at depth because of the thawing influence of the river. Some of the older test holes and the 1974 confirmation drill holes found many places where frozen silt lies at depth beneath unfrozen sandy gravel or occurs beneath frozen thaw stable gravel. In most locations the frozen silt is liquefiable when thawed. These conditions were recognized by Alyeska's field engineers, and drilling on closely spaced centers with air track equipment was done to identify areas in which a change had to be made to elevated construction to comply with Stipulation 3.3.1 It was not possible to accommodate all areas of permafrost with elevated construction, without leaving within the elevated construction some areas in which the fine-grained deposits were unfrozen. Elevated supports in unfrozen silt had to be of friction pile design, and some difficulty was encountered in obtaining the necessary bearing without lengthening the piles over that called for in the original design. In some areas, to illustrate the problem, the fluid mud flowed out of the test holes.

The lesson to be learned in this kind of valley, underlain by fine-grained deposits, is that not as much of the pipeline could be buried as at first thought, additional elevated construction in river floodplains means additional terrain disturbance by training structures and additional disturbance of fish passage and spawning beds. The question arises whether the limited possibilities for buried construction in such valleys justify the expense of numerous river crossings and training structures and whether it would not be simpler and cheaper to construct the pipeline on the upland, if it has to be largely elevated. Valleys elsewhere in which gravel and sand extended down to bedrock were, by comparison, relatively simple to design and did not have the extensive design changes that were needed in the Dietrich and Middle Fork Koyukuk River valleys.

16.0 Glacier advance and retreat

Glacier surges and a suitable monitoring program are the subject of Stipulation 3.8.1 In a remote area this kind of monitoring could be handled by periodic inspection flights, aerial photography, or by visual inspection by pipeline patrols. In a settled area or near a public highway, as is the case for all potential surge-type glaciers along the pipeline, changes in the glaciers would be readily apparent. Therefore, I recommended to APO that this Stipulation may be waived and that its provisions be incorporated into routine operation and maintenance procedures. The waiver has not been requested by Alyeska as of September 1976. Even though they have been permitted to build the line close to potentially surging glaciers, it would be to Alyeska's advantage to develop some plans on just how they would disconnect the pipe, drain it of oil, and relocate the line in case of a threat by glacier surge. Because of the economic impact of shutting down the line, some regulatory authority may be desirable to tell them when to disconnect the line and where to relocate it.

Dumping of glacial lakes and drainage of water from beneath glaciers cause exceptional floods which may be a problem where such occurrences are not accounted for in the Project Design Flood or where they exceed the Project Design Flood. These glacial-outburst floods are known on Sheep Creek, Tonsina, Klutina, and Tazlina Rivers and may be expected on the outwash streams draining Canwell and Castner Glaciers. In the latter case, the probable result will be a combination of the two discreet streams, particularly severe scour conditions, and a shift in deep scour areas. Hopefully, this is accounted for in the pipeline design. This general subject could be handled under the Stipulations on floods.

Catastrophic retreat of Columbia Glacier, as forecast by Austin Post and Mark Meier of the Survey, can affect shipping lanes leading to Valdez by discharge of icebergs from Columbia Bay into the area between Valdez Narrows and Hinchinbrook Entrance. This is not an Alyeska monitoring problem and is outside the Stipulations. However, APO called the matter to the attention of the Coast Guard and the Owner Companies' Marine Committee and other appropriate agencies, and a briefing was presented to all interested parties by Mark Meier. Presumably Water Resources Division will work directly with the Coast Guard and the Owner Companies' Marine Committee in setting up a monitoring program.

17.0 Relocation of pump stations and construction camps

17.1 Pump Station 2

The position of Pump Station 2 was moved one mile away from the nests of the peregrine falcons at Sagwon Bluff to minimize damage to the habitat and disturbance of this endangered species.

17.2 Pump Station 5 (construction camp)

Pump Station 5 is on a gravel knob that is flanked by deposits of ice-rich silt. The temporary construction camp lies on ice-rich silt which was stripped and excavated with rippers in an unsuccessful attempt to reach thaw stable material below the silt. The site was covered with gravel overlay and the buildings constructed on piling.

17.3 Pump Station 6 (construction camp)

Review of plans for Pump Station 6 showed that the construction camp on its eastern edge was situated on a steep hillside underlain by ice-rich silt. In discussions with Alyeska, APO attempted to have the camp relocated to a nearby flat hilltop where permafrost conditions were more favorable. However, the Alyeska representatives refused to agree because they would be forced to bus the men to and from the job. Proposals for construction of the camp called for making cuts as high as 40 feet in ice-rich silt to provide level areas for the camp buildings. APO authorized camp construction at the proposed location provided that the entire site be overlain with 3 feet of shot rock taken from the tank farm excavation, that the overlay material be benched to provide flat areas for roads and buildings, and that the buildings be reoriented along the land contours and be erected on piling in the permafrost. Even with this design, some environmental damage may continue after completion of the project.

17.4 Pump Station 7

Pump Station 7 was relocated from the Grapefruit Rocks to its present position under pressure from environmentalists and others who valued the scenic attributes of the rocks and from climbers who scaled them.

17.5 Pump Stations 10 and 12

Relocation of Pump Station 10 to a position farther from an active fault zone and Pump Station 12 from an area of soil instability was discussed early in the project. These matters were brought to Alyeska's attention again during the final design review, but Alyeska declined to relocate the Stations.

18.0 Rerouting the pipeline

Opportunities for rerouting the pipeline were limited after mid-1974 by their potential for delay of the project. Nevertheless, several reroutes were discussed with Alyeska, and some put into effect. The local reroutes in Atigun Pass are discussed in Sec. 11.0.

18.1 <u>Keystone Canyon</u>

Proposals for routing the pipeline through Keystone Canyon in tunnels were advanced early in the project, and the first Staff Geologist, N. B. Higgs, made a study of the bedrock geology that pointed out that tunnelling was feasible. An alternate route along the old trail west of Keystone Canyon was also proposed. However, by the time I arrived on the project, the land had been transferred to the State, and no further proposals of this type could be advanced. The present route along the eastern wall of the canyon is aesthetically undesirable because the construction scars can be seen from almost any part of the Valdez Arm area.

18.2 <u>Little Tonsina River</u>

As originally designed, the pipeline crossed Little Tonsina River at four locations. The river is a rich spawning stream and has value for the special type of king salmon that spawn there. Fisheries biologists on the JFWAT team advised APO to try to relocate the line to avoid crossing the stream, and the matter was discussed with Alyeska. A reroute was selected west of the river that would eliminate two of the crossings, and this route was constructed. Late in the negotiations for this reroute, another alternative was suggested by the Authorized Officer's Field Representative. This alternative route would have realigned the pipeline east of the Little Tonsina River along a gently sloping bench on the hillside as far north as Tonsina River. The advantages of this reroute were that it could have eliminated all four crossings of Little Tonsina, could have resulted in relocating Pumping Station 12 to better foundations, and, by relocating the Tonsina River crossing dowstream, the reroute could have been extended northward to avoid the steep, unstable cuts bordering Squirrel Creek and Rock Creek. Unfortunately, Alyeska had to reject the suggested reroute because they felt it was likely to have delayed the project.

18.3 Gulkana River

The Gulkana River crossing was relocated southward in late 1975 to accommodate redesign of the crossing from buried to elevated. About two to three miles of reroute was involved in relocating the crossing downstream. Clearing and pad construction had already taken place, and the abandoned construction work was supposed to have been rehabilitated. APO's suggestion of relocating the bridge at the site of the haul road bridge to minimize terrain disturbance was not accepted by Alyeska.

18.4 Phelan Creek

The original design called for a buried crossing of Phelan Creek and a steep ascent to the plateau that separates Phelan Creek from Delta River. The design for the ascent was originally refrigerated burial and called for construction of a refrigeration plant at the base of the hill west of Phelan Creek. The APO Staff aesthetics man called attention to the conspicuous position of the plant with respect to travellers' view along the Richardson Highway and requested that the pipeline be built down the broad braided channels of Phelan Creek to its confluence with Delta River. This reroute would have avoided the refrigerated burial and an area of ice-rich soils on the plateau between the two streams. APO's case was weakened when JFWAT discovered at the last minute that Phelan Creek is a fish stream and objected to the reroute. As built, the original alignment was used, and after a suitable period of time, Alyeska eliminated the refrigerated burial design, substituting instead elevated supports, an even more aesthetically distasteful visual impact than the refrigeration plant.

18.5 Eielson to Delta Junction

A major reroute of the pipeline south of the Tanana River between Eielson Air Force Base and Delta Junction was advocated by the Survey and by Alyeska's consultants early in the project, but was rejected. The matter was brought up again, but not formally proposed by APO.

18.6 South Fork Koyukuk River to Fort Hamlin Hills

A change in the pipeline route from the South Fork Koyukuk River to the Fort Hamlin Hills following the ridge tops might have saved 30 miles of construction and would have avoided many of the steep slopes along Prospect, Bonanza, and Fish Creeks. The possible reroute was discussed at APO, but never formally proposed to Alyeska. However, on future lines, ridgetop routes should be looked at carefully because they offer few soils problems and afford opportunity for burying the pipe, no river crossings, generally moderate to low slopes (as compared to up and down steep slopes crossing valleys at right angles), and little need for long haul of pad material.

18.7 Middle Fork Koyukuk River south of Coldfoot

The pipeline was designed to follow the Middle Fork Koyukuk River beneath steep hillsides along its east bank. An overland reroute was effected under pressure from fisheries biologists of JFWAT to preserve the habitat for arctic grayling. The reroute should have been extended southward to relocate sections of pipeline in which unexpected permafrost conditions forced construction of elevated pipe in the floodplain, sections subject to riverbank erosion, and a large number of training structures.

18.8 Atigun River

Pipeline design called for a route down the Atigun River and four crossings of the river in its meandering reaches south of Pump Station 4. However, the haul road was constructed near the mountains east of the river. The poor aesthetics of two widely separated rights-of-way connected by access roads in this beautiful mountain valley prompted APO to propose that the pipeline be moved to a position near the haul road. The proposal was readily agreed to by Alyeska because it had been under consideration as a desirable alternative with cost savings. Four crossings of the Atigun River were eliminated.

One of the major reroutes of the early days of the project was shifting the line from its route down the canyon of Atigun River (from Galbraith Lake to the Sagavanirktok River) to the present route north to Kuparuk River and northeast to the Saganvanirktok River near Slope Mountain. With the construction problems encountered in relatively simple areas, elimination of the hard-to-construct Atigun canyon section of pipeline was a very wise move.

18.9 Rerouting to combine pipeline and haul road

After the haul road was pushed through in an alignment that was separate from the planned pipeline route, APO made a largely unsuccessful effort to relocate the pipeline at many sites north of the Yukon to a position adjacent to the haul road. The purpose of these suggested reroutes was to minimize terrain disturbance and, in areas of buried pipeline construction, to use the haul road as the work pad. Naturally, Alyeska resisted the suggestion for various reasons, but notably because they would have to issue new drawings, compute new designs, and re-do the subsurface exploration. Only a few of the 16 proposed relocations were put into effect, and none of these combined road and work pad.

19.0 Icings

Icings (aufeis) of the floodplain type occur along several reaches of Phelan Creek, and Delta, Middle Fork Koyukuk, Dietrich, Atigun, and Sagavanirktok Rivers, where the pipeline is buried in alluvium. In a few areas, where elevated mode has been dictated by unexpected frozen fine soils, the elevated line has been diked to prevent incursion of icings. Despite these dikes and other designs, ice reached the elevated pipe at several locations and water diverted by icings washed across the work pad beneath elevated pipe in some sections along the Dietrich River. Water Resources Division of the Survey has mapped the extent of these icings, with notations on the probable cause, as part of their pipeline-related arctic hydrology program.

Problems with icings above the buried line may not be fully understood until the pipeline is filled with warm oil and a heat source is created in the streambed. Whether the heat source will be sufficient to alter the hydrology of the icing and affect its formation is unknown. Also unknown is the effect of a heated buried pipe in creating an ice-walled channel through which the early runoff flows during the breakup. Scour depth under such flow conditions may be greater than that calculated for a normal open river channel under similar discharges. It remains to be seen whether the warm pipe in the streambed in river crossings will cause icings to form where none have formed in the past.

Generation of icings by blockage of ground-water flow at deeply-frozen sections of work pad has been noted already along the line, but has not been studied in detail. Once warm oil passes through the buried pipe, icing conditions may be expected to change significantly, and icings that are now formed by discharge of ground-water dammed behind the deeply frozen work pad may not reform, and others caused by discharge of ground water in the thaw bulb around the warm pipe may be generated. Alyeska has supposedly selected the pipeline route to minimize environmental disturbance due to icings, but it remains to be seen where icings will develop once the line is put into service. These icings should be watched carefully for their effect on integrity of the pipeline, passability of the haul road, and other environmental considerations as part of the Water Resources Division monitoring effort.

20.0 Avalanches, slushflows, and mudflows

Preliminary studies of the avalanche, slushflow, and mudflow hazard have been made by Alyeska at the terminal, in Atigun Pass and on the Atigun River valley as far north as Pump Station 4. The pipeline route has been chosen to present the least possible exposure to these hazards and is buried through Atigun Pass, largely because of this hazard. Alyeska's consultant says there is no avalanche danger at the Valdez Terminal.

The pipeline has been relocated across mudflow cones on the east side of the Atigun River valley south of Pump Station 4. The route seems to be beyond the limit of recent mudflow and slushflow activity, but within the limits of mudflows and slushflows that were active more than 75 years ago. Several of the test borings in this segment show that buried soil profiles separated by mud and rocks lie on at least 20 feet of ice.

The age and history of mudflows and slushflows in the Atigun River valley has been under study by R. D. Reger of the Alaska Geological and Geophysical Survey. Results of this study and further research certainly merit attention during the life of the pipeline, not only for an accurate analysis of the potential danger to the pipeline from the 100-year or project-design mudflow or slushflow, but also for its scientific interest.

Appendix C

The attached list of action items and unresolved issues between Alaska Pipeline Office and Alyeska is appended to provide an illustration of the types of unresolved problems that were being discussed at any one time by the Technical Staff of APO. The list was prepared on February 23, 1976, and was submitted to Alyeska as a work-list for guidance in reducing the number of disputed items. Most of these issues have since been resolved.

Appendix C

List of action items and unresolved problems, February [illegible], 1976

1.3 RIVER CROSSINGS

ITEM			NEXT ACTION BY	REQUIREMENT
1.3.1		Scheduling of construction	APSC	Resolve conflicts of schedule with JFWAT designated critical times.
1.3.2.		Assure fish passage through culverts and low water crossings	APSC	Correct improper construction.
1.3.3		River crossing design problems	APSC	
1.3.3.1		Sulphide Gulch AS2	APSC	Data on protection against avalanches and avalanche generated winds.
1.3.3.2	2RX5	Gulkana River	APSC	Furnished pile load data.
1.3.3.3	4RX6	Yukon River Bridge	APO	Complete review of pier scour calculations, guard railing, pipe support system and dynamic analysis.
1.3.3.4	5/6RX1	MF Koyukuk River (AS100) (NTP 5/6RX-1 not yet issued)	APSC	Submit redesign for transition both banks, and plan for excavating trench and controlling siltation.
1.3.3.5	3ES-1	Engineer Creek AS61 211+05/211+22	APSC	Furnish design of crossing construction hold.
1.3.3.6	3ES-1	Goldstream AS61 336+01	APSC	Furnish design of crossing construction hold.
1.3.3.7	3RC-3	Suggested relocation of pipeline to avoid 4 stream crossings AS55 Sta. 583+80 to 660+00	APSC	Respond to suggestion.
1.3.3.8	4RX-3	Prospect Creek redesign	APSC	Redesign and reapplication for NTP requested for elevated crossing. New designs show elevated steel too low and not deep enough for scour.
1.3.3.9	4RX5	Jim River, remode to AG	APSC	Hold for submittal of revised NTPA, as requested, APO letter 1162.
1.3.3.10	4RC-1	Variance to Stip. 3.6.1.1.1.1 not approved for 1-1.37 and was approved for Fish Creek provided active channels crossed by clear span	APSC	Follow through NTP 4RC-1.

1.3 RIVER CROSSINGS (CONT'D)

ITEM			NEXT ACTION BY	REQUIREMENT
1.3.3.11	5/6RX6	Hydraulic data	APSC	Submit backwater profile including effect of road bridge, proposed training structures. Bridge pier and footings should be based on channel changes caused by construction. reassess rip rap size for spurs 1 and 2. Additional spur shank rip rap. Provide B* toes for spurs.
1.3.3.12	5/6RX12	Pile data for crossing	APSC	Supply pile data for Dwng. DOOC1281.
1.3.3.13	5/6RX3		APSC	Supply plans and schedule and changes in Dwng. DOOC375.
1.3.3.14	5/6RX4		APSC	Supply backwater calculations.
1.3.3.15		Plate girder bridges, piling		Require hydraulic and structural reviews Hammond and M. FK Koyukuku R. AS101. Provide all supporting data on revised ice loadgins and pile redesign.
1.3.3.16		Rip rap - Tech. Spec. 2.21 (Rev. 2)	APSC	Respond to APO Letter 780.

1.1 VSM DESIGN AND INSTALLATION

ITEM		NEXT ACTION BY	REQUIREMENT
1.1.1	Efficiency of thermal VSM	APSC	Furnish test data Chena Hot Springs site.
1.1.2	Use of thermal VSM's in sand and gravel with limited fines	APSC	Data supporting criteria are insufficient.
1.1.3	Thermal VSM's in thawed soils	APSC	Data supporting criteria are insufficient.
1.1.4	VSM in massive ice	APSC	Date supporting criteria are insufficent data. DCR's cannot be approved without approved design criteria e.g. Atigun reroute.
1.1.5	Adfreeze shear strengths, selected sites	APSC	Data justifying design values inadequate.
1.1.6	Freezeback/Hydrotests	APSC	Test data insufficient for approval respond to thawed - pull test report due 2/17/76.
1.1.7	Freezeback plan	APSC	Furnish as required in NTPs.
1.1.8	Design load criteria		
1.1.8.1	Vertical load	APSC	Depends on VSM load test results.
1.1.8.2	Lateral load	APO/APSC	Respond to APSC report due 2/17/76, no response from APSC on comments on structural review of rough draft of 11/75: APO review based on soild parameters in 10/75 draft.
1.1.9	Field tests	APSC	Furnish results.
1.1.10	Split VSM criteria	APO	Supporting data (DCR) in reveiw - comments by 2/13/76.
1.1.11	Driven VSM and H piles (Spec. 2.31)	APSC	Criteria should be submitted for review.
1.1.12	Freezing point depression, unfrozen water content	APSC	Data should be submitted for review.
1.1.13	VSM grout strength	APO/APSC	Supporting data reviewed by 2/13/76. Additional data on actual loads needed from APSC

1.2 WELDING

ITEM		NEXT ACTION BY	REQUIREMENT
1.2.1	Sonic testing of welds	APSC	Furnish results.
1.2.2	QA audit, Sections 1, 4, 5/6(working)	APSC	Furnish audit.
1.2.3	Production weld test, partially submitted by APSC Letter 1320	APSC	Funish remainder of data.

1.3.4 RIVER TRAINING STRUCTURES

ITEM			NEXT ACTION BY	REQUIREMENT
1.3.4.1		Scheduling construction	APSC	Furnish schedule to allow assessment of impact on fish.
1.3.4.2.	2RX2	Spur dikes, Phelan No. 2 AS35 Sta. 5578+00 to 5609+70	APSC	Approval deferred (NTP).
1.3.4.3	2RX2	Bank rip rap AS35 Sta. 5651+00	APSC	Approval deferred (NTP).
1.3.4.4	2RX2	Phelan #3 spurs and continuous dike AS36A Sta. 5967+00 to 6064+00	APSC	-
1.3.4.5	2RX3	Delta #1 spurs AS38 Sta. 6350+00 to 6381+00	APSC	-
1.3.4.6	2RX3	Delta #2 AS38 Sta. 6329+77, spurs	APSC	-
1.3.4.7	2RX3	Delta #2 spurs AS38 6390+70 to 429+25	APSC	-
1.3.4.8	2RX3	Delta #3 spurs, AS38 Sta. 6436+71 to 6542+00	APSC	-
1.3.4.9	2RX1	Tanana guidebanks AS47, 9198+05 to 9230+15	APSC	Provide redesign.
1.3.4.10	4RX2	No. FK Bonanza Cr. spurs AS89 Sta. 1190 and 1205+40	APSC	Redesign spurs.
1.3.4.11	4BC-1,4EC-1	Spurs AS97 Sta. 525+00 to 712+00	APSC	Redesign spurs, armor tip.
1.3.4.12	4EC-1	Spurs AS97 Sta. 805+00 to 840+00	APSC	Redesign spurs, armor tip.
1.3.4.13	4BC-1	Spurs AS98 Sta. 1047+00 to 1119+00	APSC	Redesign spurs.
1.3.4.14	4EC-1	Spurs AS99 Sta. 157+00 to 171+00	APSC	Redesign spurs.
1.3.4.15	5/6RX1	M. FK Koyukuk R. AS100 Sta. 487+60 to 610+00	APSC	Resubmit NTPA with redesign.

1.3.4 RIVER TRAINING STRUCTURES (CONT'D)

ITEM			NEXT ACTION BY	REQUIREMENT
1.3.4.16	5/6RX2, 5/6EC1	Spurs AS101 Sta. 610+00 to 692+46	APSC	Redesign spurs; revise hydraulics.
1.3.4.17	5/6EC-1	Dike, tip armor AS101 Sta. 716+00 to 725+00	APSC	Revise designs; revise hydraulics.
1.3.4.18	5/6BC-1	Spurs AS101 Sta. 835+00 to 859+00	APSC	Revise designs; revise hydraulics.
1.3.4.19	5/6EC-1	Spurs, AS102 Sta. 1127+50 to 1997+00	APSC	Revise designs; revise hydraulics.
1.3.4.20	5/6BC-1, 5/6EC-1	Continuous dike AS103 Sta. 1203+10 to 1268+37	APSC	Revise designs; revise hydraulics.
1.3.4.21	5/6EC-1	Guidebank AS104 Sta. 1522+00 to 1548+51	APSC	Revise designs; revise hydraulics.
1.3.4.22	5/6BC-1	Guidebank AS104 Sta. 1749+00 to 1807+00	APSC	Revise designs; revise hydraulics.
1.3.4.23	5/6BC-1, 5/6EC-1	Spurs, AS105 Sta. 1994+00 to 2126+00	APSC	Revise designs; revise hydraulics.
1.3.4.24	5/6BC-1	Spurs, AS106 Sta. 2126+00 to 2197+00	APSC	Revise designs; revise hydraulics.
1.3.4.25	5/6BC-1	Rip rip banks AS106 Sta. 49+00 to 169+00	APSC	Revise designs; revise hydraulics.
1.3.4.26	5/6BC-1	Rip rap banks AS107 Sta. 264+88 to 346+00	APSC	Revise deisngs; revise hydraulics.
1.3.4.27	5/6BC-1	Spurs AS108 Sta. 633+60 to 651+44	APSC	Revise designs.
1.3.4.28	5/6BC-1	Spur AS109 Sta. 1096+00	APSC	Revise design.
1.3.4.29	5/6BC-1	Dike and plug AS110 Sta. 55+45	APSC	Revise design.
1.3.4.30	5/6EC-1, 5/6BC-1	Spurs, AS123 Sta. 22+00 to 121+50	APSC	Redesign.

1.3.4. RIVER TRAINING STRUCTURES (CONT'D)

ITEM			NEXT ACTION BY	REQUIREMENT
1.3.4.31	5/6BC-1	Spurs, AS124 Sta. 226+00 to 425+10	APSC	Redesign.
1.3.4.32	5/6EC-1	Guidebank AS125 Sta. 425+10 to 470+00	APSC	Redesign.
1.3.4.33	5/6BC-1	Guidebank AS126 Sta. 887+00 to 936+00	APSC	Redesign
1.3.4.34	5/6BC-1	Spur and guidebank AS127 Sta. 1140+00 to 1200+48	APSC	Redesign.
1.3.4.35	5/6BC-1	Spurs AS129 Sta. 508+00 to 560+00	APSC	
1.3.4.36	5/6BC-1	Channel plugs AS131 Sta. 1005+00 and 1085+00	APSC	

1.4 FAULT CROSSINGS

ITEM			NEXT ACTION BY	REQUIREMENT
1.4.1		High loading of VSMs	APSC	Furnish design backup data.
1.4.2	2BC-2	Clearwater Fault AS46/47 Sta. 8910+17 to 9120+28	APSC	Revise design to assure PL integrity.
1.4.3	2ES-2	McGinnis Glacier Fault AS37 Sta. 6218+50 to 6285+00	APSC	Awaiting redesign to AG from Sta. 6192+02 to 6218+50
1.4.4	2ES-2	Denali Fault AS37 Sta. 6173+02 to 6192+02	APSC	Redesign to north end anchoring system; gravel berm; shoe design.

ITEM			NEXT ACTION BY	REQUIREMENT
1.5		Shallow slides, criteria for	APO	Review documentation.
1.5.1	1RC1.2	Klutina cut, ice content and stability AS19 Sta. 458+14 to 462+94	APSC	Review design based on borings to assure pipeline integrity.
1.6		Thaw plug stability	APO	Review documentation.
1.7		Maximum allowable burial depth	APO	Complete review.
1.8		Tie-in, bends		
1.8.1		Relaxation of AG Pipeline tie-in temperatures	APO	Complete review.
1.8.2		Tech. Memo 33 Rev. 1 (tie-in)	APO	Complete review.
1.8.3		Tie-in method, insulated pipe	APSC	
1.8.4		Use of fabricated ells (AS1-11, 36, 36A, 38, 41 and 47)	APSC	Furnish documentation on effects of local stresses at bends made at fabricated elbow caused by proposed methods of thrust blocks ells have radius of 12' to pipe axis instead of field bends which have minimum radius of 120'.
1.8.5		Field bend anomalies	APSC	Furnish allowable limits on magnitude of permanent wrinkling observed during field bending operations.
1.8.6		Bends in relation to water table	APSC	Recalculate with water table at surface.
	2RX2	AS38 5463+40, 6017+28, 6026 +70		
	2RX3	AS38 Sta. 5650+39.5		Construction hold for documentation on pipe stress effects and design of thrust block.
	2RX3	Hold on construction of bends		Recalculated with water table at surface.
	5/6RX7	AS108, Sta. 514+90, 525+50, 564+95, 569+70		Recalculate with water table at surface.
1.8.7	2RX2	Pipe stress effects and esign of thrust block	APSC	Provide analysis

ITEM			NEXT ACTION BY	REQUIREMENT
1.9		Bedding and padding	APSC	Provide allowable span dimensions where as-builts deviate from Tech. Specs.; QA procedures for out of spec. violations.
1.9.1		Tech. Memo 23	APO	Complete review.
1.10		Remodes and relocations		
1.10.1	5/6BC-1	Atigun Pass, AS110 Sta. 186+00 to 249+00, relocation	APSC	Review DCR E-5-46(Sta. 212+00 to 249+00) and prepare DCR for Sta. 186+00 to 212+00.
1.10.2		South side Hess Cr. (DCR)		Provide request for variance Stip. 3.3.1
1.10.3	2ES2	Remode BG to AG AS37 Sta. 6192+02 to 6218+50	APSC	Complete subsurface investigation. Submit DCR.

ITEM			NEXT ACTION BY	REQUIREMENT
1.11		Deep burial with overlying ice-rich soils	APSC	Submit report EW-008.1A.
1.11.1		Spanning ice-rich soils	APSC	Furnish allowable span dimensions for various subsurface and operating conditions.
1.12		Special burial		
1.12.1		Coefficient of friction	APSC	Provide documentation of conditions for 4.0 psi design criteria and comparison of results for actual loading conditions.
1.12.2	4ES1	Sagbend animal crossings	APSC	Results of bore holes and evaluation of thaw-settlement have not been furnished for any of designs, e.g. AS83, Sta. 490+00 to 554+00; AS115, 476+00 to 478+00; AS116, Sta. 610+00 to 620+00, 804+00 to 813+00, AS117, Sta. 863+00 to 873+00, 1095+00 to 1105+00; AS119, Sta. 1406+00 to 1416+00, 1506+00 to 1516+00.
1.12.3	2BC-2	Criteria for refrigerated burial AS26, Sta. 2786+63 to 2889+47 and 3024+47 to 3148+00	APSC	Provide borings for evaluation of design and monitoring program.
1.12.4	5/66BC-1	Atigun Pass AS110, Sta. 130+00 to 186 +00	APSC	Provide special bury design, borings justifying relocations, if any.
1.12.5	4ES-1	Sagbend animal crossing AS96, Sta. 300+00 to 350+00	APSC	Provide and verify design.
1.12.6		Criteria for refrigerated burial	APO	Complete review.
1.13		Resolution of type of corrective action by APSC where big game crossings have been constructed out of spec.	APSC	Final resolution pending.

ITEM			NEXT ACTION BY	REQUIREMENT
1.14		Field design change manual, V.1-3	APSC	Respond to APO comments. APSC using outdated unapproved manuals.
1.15		Grouting piling	Office Pipeline Safety Opns.	Respond to design and to APSC letter (Aug. 75) on corrosion.
1.16		Drainage criteria	APSC	Respond to comments on rept. A/C 004.1A.
1.17	5/6RC-2	Encroachments	APSC	Respond to disapproval of encroachment variance requests 13.8 through 13.10, 14.14 through 14.18, and 14.52.
1.18		Pipe guage repair criteria	APSC	Revise applicable tech. specs. as per recommended acceptable limits.
1.19		Protective tape	APSC	Submit methods of applying primer as per OPSO Letter and submit long-term shear strength of tape at critical bends.
1.20		Work pad/snow pad		
1.20.1	1RC1.2	Specifies maximum snow pad AS17, Sta. 1350+07 to 1464+30, AS18, Sta. 255+89 to 285+00, 285+90 to 310+00, AS19 Sta. 310+00 to 476+00	APSC	Justify construction without snow pad.
1.20.2	1RC1.2	No work pad, AS18, Sta. 10+20 to 11+12	APSC	Justify use of gravel pad.
1.21	1BC-2	Rock stability AS4, Sta. 895+68 to 1107+16, Keystone Canyon	APSC	Furnish report in preparation.
1.22	RGV-XX-1	Typical drawings	APSC	Furnish typical drawings and correct 020-C102.
1.23	1RC1.2	Water level and slope stability, Rock Creek(APSC Letter 926; APO reply S.N. P001-APO-0878	APSC	Provide logs and water level measurements in piezometer holes and revised stability analysis.
1.23		Cathodic Protection	APSC	Submit plan.
1.24		Corrosion protection, control	APSC	Furnish status of outstanding review comments.

ITEM		NEXT ACTION BY	REQUIREMENT
1.25	Start-up procedures	APSC	Furnish as soon as possible.
1.26	Telluric currents	APSC	Furnish measurements and analysis.
1.27	Seismic and fault monitoring systems	APSC	Furnish designs.

2.0 PUMP STATIONS

ITEM			NEXT ACTION BY	REQUIREMENT
2.0		Pump stations	APSC	Require quality control measures for installation of brineline system. See also APO Letter S.N. P001-APO-163.
2.1		Pump Station 2 - Brineline	APSC	Submit status of brineline system.
2.2		Corrosion plan	APSC	Submit status of outstanding review comments on corrosion protection plan.
2.3		Thermal cracking tank farm dikes	APSC	Furnish documentation verifying adequacy of dikes subject to thermal cracking.
2.4		Pump station soil samples	APSC	Furnish data.
2.5	PXX-TK-1	Relief tanks	APSC	Correct violation of Federal regulations for tank vent design.
2.6		Start-up procedures	APSC	Furnish as soon as possible.
2.7		Seismic evaluation	APSC	Provide.
2.8		Tank foundations		
2.9		Pipe supports		

3.0 TERMINAL

ITEM			NEXT ACTION BY	REQUIREMENT
3.1		Status of audit on storage tank bottom shell to annular plate welds	APSC	Furnish.
3.2		West tank farm	APSC	Re-evaluate major cuts.
3.3		Reinforced earth, East tank farm dikes (concept approved)	APSC	Site-specific application of design needed for review.
3.4		Thermal cracking, tank farm dikes	APSC	Documentation to verify adeuqcy against cracking.
3.5		Pipe supports	APSC	Document adequacy.
3.6		Pile tests	APSC	Demonstrate adequacy.
3.7	T-GO-3	West Meter Bldg. Main Fire Pump Bldg., Scraper Meter Rec. Bldg., Fuel Dock (APO Letter 976)	APSC	Require drawings.
3.9	T-CB-1	Control Building framing (APO letter 1233)	APO	Complete review.
3.10	T-BW-3	Rock anchors, drawing discrepancy sealing details (APO Letter 901)	APO	Complete review.
3.11		Analysis of rock slide and cut back of power plant and vapor recover bldg.	APO	Complete review.
3.12		Seismic evaluation ??		
3.13		Snow load on tanks and buildings	APSC	Provide analysis of suitability of design for current (2/76) conditions.
3.14		Start-up procedures	APSC	Furnish as soon as possible.
3.15		Soil samples	APSC	Submit results.

4.0 FUEL GAS LINE

ITEM			NEXT ACTION BY	REQUIREMENT
4.0	5/6GF-1	Fuel gas line		
4.1	5/6GF-1	Fuel gas line drawings	APSC	Construction in progress without updated drawings; correct.
4.2	5/6GF-1	Snow pad width		Correct violations of approved snow pad width.
4.3				
4.4		Start-up procedures		Furnish as soon as possible.

5.0 COMMUNICATIONS/SUPERVISORY CONTROL SYSTEM

ITEM		NEXT ACTION BY	REQUIREMENT
5.1	Communications system. VHF anntenna and mounting RGV and tower		
5.1.1	Communications system: Look Angel vs. exhaust		
5.2	Supervisory control system:		
5.2.1	Terminal control schematic	APO	Complete review.
5.2.2	Pump station control schematics	APO	Complete review.
5.2.3	Pump Station 5 hybrid logic	APO	Complete review.
5.2.4	Leak detection sensor verification	APO	Complete review.
5.2.5	Test and check out plan	APO	Complete review.
5.3	Aux. supervisory control system		
5.3.1	RGV instrumentation and schematic		
5.3.2	PS instrumentation		
5.3.3	Test and check out plan		
5.4	Seismic monitoring system	APSC	Submit design.
5.4.1	Location and identification of detectors	APSC	Submit design.
5.4.2	Recording and transmission (VHF)	APSC	Submit design.
5.4.3	Evaluation procedure (soft ware)	APSC	Submit design.

6.0 SUPERPIG

ITEM		NEXT ACTION BY	REQUIREMENT
6.1	Reliability of wheels on ovality and distance-measuring elements of transducer section	APSC	Furnish information.
6.2	Operational tests of wheels	APSC	Will action be completed before 1976 Labehead Tests?
6.3	If wheel width reduced from 1 inch to 50/1000 inch, what corrections to spring loading will be taken to prevent excessive gouging of pipe interior	APSC	Furnish information.
6.4	Transducer tilt	APSC	Furnish method of verification.
6.5	Additional unperforated scraper cups	APSC	Will they be added to battery and/or transducer section?
6.6	Running distances for scraper of weight and configuration of superpig	APSC	Are distances of 270, 315, and 215 miles realistic?
6.7	Running data for scrapers	APSC	Furnish data.
6.8	Reliability of scrapers operating with one solid cup upling other perforated cups when moving the weight of the pig	APSC	Furnish data.
6.9	Will superpig be modified to permit rotation and distribute cup wear	APSC	Furnish data.
6.10	Rotation of superpig	APSC	How will rotation be assured?

7.0 EROSION CONTROL, REVEGETATION AND REHABILITATION

ITEM		NEXT ACTION BY	REQUIREMENT
7.1	Scope of rehabilitation, and revegetation (RHB-014.1)	APSC	See APO Letter S.N. POOI-APO-1231, dated 11/13/75.
7.2	Rehabilitation planning policy (Tech. Memo 26)	APSC	See APO Letter S.N. P001-APO-1145, dated 10/17/75 and proposed changes to be submitted by APSC as a DCR in 3/76.
7.3	Field design change manual, V.4	APSC	Respond to comments and revise manual. See APO Letter S.N. P001-APO-1233, dated 11/13/75.
7.4	Restoration winter trails	APSC	See our summary letter S.N. PGP-3013-APO-14, Re: Violations Tardiness of Work.
7.5	Procedures for transplanting	APSC	Reference APSC response to 6/20/75 Preliminary design review. APSC does not consider transplanting native vegetation erosion control or need for revegetation to be made a part of construction effort.
7.6			
7.7	Erosion control plan and schedule	APSC	Furnish.
7.8	Test results, evaluations of field data used to establish design criteria	APSC	Furnish as per stips. 1.1.1.1.2, 1.1.1.23 and 1.7.4.3(2).
7.9	Compliance with Stip. 1.18, and 3.92	APSC	Improve QA to make responsible to president of APSC, not to operating divisions (1.18) and provide QC for enforcement of Stip. 3.9.1 and 1.7.
7.10			
7.11	Scheduling of EC-1 and EC-2 work	APSC	If EC-2 work is delayed to 1977, FJWAT may need to maintain current staffing level to evaluate effects of the work.
7.12	Slope erosion	APSC	Require report EW-008.1A referenced in Rept. EW-008.4 before final design can be reviewed.

8.0 OPERATION AND MAINTENANCE (O & M) AND O & M PROCEDURES

ITEM		NEXT ACTION BY	REQUIREMENT
8.1	Details on O & M roads and other facilities	APSC	Furnish plan.
8.2	O & M facility proposals	APSC	Respond to State of Alaska and Bur. Land Mgmt comments.
8.3	Access road, material sites, disposal sites as-built drawings for verification and case files - Re: aesthetics, restoration, etc.	APSC	Furnish drawings.
8.4	VIE and detailed aesthetic plans	APSC	Furnish plans.
8.5	Define acceptable performance on restoration program	APSC	Need to be able to measure response response and results.
8.6	Pig sequencing	APSC	Furnish plan.
8.7	Relief valve operation	APSC	Furnish plan.
8.8	Diked area snow and rain removal	APSC	Furnish plan.
8.9	Refrigeration maintenance	APSC	Furnish plan.
8.10	Communication sites	APSC	Furnish operating plan.
8.11	Deactivating camps, fuel facilities sewage, etc., restoration	APSC	Furnish plan.
8.12	Seismic evaluation	APSC	Provide.

9.0 GENERAL

ITEM		NEXT ACTION BY	REQUIREMENT
9.1	Oil spill contingency plan	APSC	Furnish as far in advance as possible.
9.1.1	Oil spill plans during construction	APSC	Experience in major spills at camps shows that many persons are unaware of contingency plans and each suitable equipment.
9.2	Lack of Environmental Quality Assurance (QC)	APSC	JFWAT monitors are performing duties that are responsibility of permittee.
9.3	Fuel handling	APSC	Improve monitoring at camps and pump stations.
9.4	Sewage treatment	APSC	Criteria for performance not yet determined pending approval EAP permits.
9.5	Design Change Request (DCR) problems	APSC	Provide adequate supporting data.