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Environmental Impact Analysis: The Example of the Proposed Trans-Alaska Pipeline

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By David A. Brew

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ROGERS C. B. MORTON, *Secretary*

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ABSTRACT

The environmental impact analysis made as required by the National Environmental Policy Act of 1969 for the proposed trans-Alaska pipeline included consideration of the (1) technologically complex and geographically extensive proposed project, (2) extremely different physical environments across Alaska along the proposed route and elsewhere in Alaska and in Canada along alternative routes, (3) socioeconomic environment of the State of Alaska, and (4) a wide variety of alternatives.

The analysis was designed specifically to fit the project and environment that would be affected. The environment was divided into two general parts—natural physical systems and superposed socioeconomic systems—and those parts were further divided into discipline-oriented systems or components that were studied and analyzed by scientists of the appropriate discipline. Particular attention was given to potential feedback loops in the impact network and to linkages between the project's impacting effects and the environment.

The results of the analysis as reported in the final environmental impact statement were that both unavoidable and threatened environmental impacts would result from construction, operation, and maintenance of the proposed pipeline system and the developments related to it. The principal unavoidable effects would be (1) disturbances of terrain, fish and wildlife habitat, and human environs, (2) the results of the discharge of effluent from the tanker-ballast-treatment facility into Port Valdez and of some indeterminate amount of oil released into the ocean from tank-cleaning operations at sea, and (3) the results associated with increased human pressures of all kinds on the environment. Other unavoidable effects would be those related to increase of State and Native Corporation revenues, accelerated cultural change of the Native population, and extraction of the oil and gas resource. The main threatened environmental effects would all be related to unintentional oil loss from the pipeline, from tankers, or in the oil field. Oil losses from the pipeline could be caused by direct or indirect effects of earthquakes, destructive sea waves, slope failure caused by natural or artificial processes, thaw-plug instability (in permafrost), differential settlement of permafrost terrain, and bed scour and bank erosion at stream crossings. Oil loss from tankers could be caused by accidents during transfer operations at Valdez and at destination ports and by casualties involving tankers and other ships.

Comparison of alternative routes and transportation systems and of their environmental impacts provided information which indicates to the author that one corridor containing both oil and gas pipelines would have less environmental impact than would separate corridors. Considering also the threat to the marine environment that any tanker system would impose and the threat that zones of high earthquake frequency and magnitude would impose on pipelines, it is apparent to the author that environmental impact and cost would be least for a single-corridor on-land route that avoided earthquake zones. The alternative trans-Alaska–Canada routes would meet these criteria.

The decisions of the U.S. Department of the Interior, the U.S. Congress, and the President of the United States in favor of the proposed trans-Alaska pipeline system indicate the relative weight given by the decision makers in balancing the importance of potential environmental consequences against the advantages to be derived from rapid resource development.

INTRODUCTION

The precedents that have been and will be set by the proposed oil-pipeline system and soon-to-be proposed gas-pipeline system in Alaska will have far-reaching implications for petroleum development in the arctic parts of the Western and possibly the Eastern Hemisphere. Some of the most important precedents will concern the acquisition, analysis, and use of environmental data. The Alaskan example is of interest to all groups involved in arctic resource development because it provides information on predicted environmental impacts and on the methods used in arriving at the predictions.

This paper represents an attempt on the part of the author to summarize pertinent elements of the experience derived from the preparation of a complex environmental analysis for the benefit of others concerned in similar endeavors.

The purposes of this paper are (1) to describe the reasons for analyzing environmental impact and discuss (a) the implications of the National Environmental Policy Act (NEPA) of the United States and of similar laws in other countries to governmental and industrial decision-making processes, (b) the economic and public interest factors in the industrial decision-making process, and

(c) the basic need to develop ways of minimizing the environmental costs that mankind must pay now and in the future; (2) to describe the general methodology needed to analyze environmental impact rigorously and objectively; (3) to describe in some detail how this methodology was applied to the proposed trans-Alaska pipeline and related systems; (4) to describe the main types of impact predicted from that analysis; (5) to examine the alternatives to the proposed pipeline; and (6) to analyze briefly from the author's viewpoint the approval of the proposed trans-Alaska oil-pipeline system as an example of the degree to which environmental considerations influenced the decision-making process.

It is difficult to discuss these points disinterestedly, without advocating one view or another, because many of the issues and factors are politically sensitive and subject to opposing interpretations when differing value frameworks are used. Nevertheless, because the lessons to be learned from the Alaskan pipeline example are important, the author has attempted to examine the ramifications of the impact analysis and of the decision deliberately and objectively.

This circular is modified from a paper prepared for presentation to the Fifth International Congress of the Fondation Francaise d'Etudes Nordiques (Brew and Gryc, 1974). The interested reader is referred to that paper for a more complete discussion of the analysis of the government's decision (point 6, above).

PROPOSED TRANS-ALASKA PIPELINE

The Secretary of the Interior of the United States has granted a permit to the Alyeska Pipeline Service Company for a 48-inch oil-pipeline right-of-way across Federal land in Alaska between a point south of Prudhoe Bay on the North Slope and Port Valdez, an arm of Prince William Sound, on the south coast (fig. 1). The company will design, construct, operate, and maintain the pipeline system.

The pipeline will be about 789 miles (1,270 km) long, some 641 miles (1,030 km) of which will be across Federal land. The pipeline system will also include pump stations, campsites for use during construction, airfields for use during both construction and operation of the pipeline, a communication system, lateral access roads, and pits or quarries for construction materials. The marine terminal site on Port Valdez will consist of a tank farm, dock, and related facilities. Prior to construction of the pipeline north of the Yukon River, a road will be built for access and the movement of equipment, materials, and personnel during construction. This road, which is proposed to become part of the State of Alaska highway system, will be about 361 miles (580 km) long.

Construction of the proposed pipeline system will result in three additional significant developments not directly included in the pipeline application: (1) an oil field complex at Prudhoe Bay on the North Slope, (2) a probable gas transportation system, and (3) a marine tanker system operating between Port Valdez, Alaska, and various destination ports.

The pipeline and its related developments will constitute a complex engineering system that will result in changes in the existing abiotic, biotic, and social and economic systems of Alaska and adjacent areas. In addition, the pipeline system will affect the economics of energy use and the strategy of energy supply in the United States. The phrase "environmental impact" has gained general use in denoting changes that would occur in existing systems if a proposed course of action were to be adopted.

REASONS FOR ANALYZING ENVIRONMENTAL IMPACT IN THE ARCTIC AND OTHER REGIONS

There are philosophical, economic, social, and legal reasons for attempting to analyze environmental impact in the Arctic and elsewhere. These different reasons are linked together in a complicated way, but the social reasons (those pertaining to the physical well-being of humans and their surroundings) have been dominant and have in some countries led to legal requirements.

People have only recently realized that some of the effects of the industrial revolution are potentially severely detrimental to the life support system that must sustain present and future generations. The natural environment, as contrasted with the social and economic environment that man creates, is particularly susceptible to damaging stresses.

Many now believe that the greatest long-term benefits of health and enjoyment are possible only if the natural environment is maintained in a condition as close as possible to that existent before the world population explosion and industrial revolution. If people are to work toward this goal, then it is necessary to strive systematically to repair the damage already done to the natural environ-

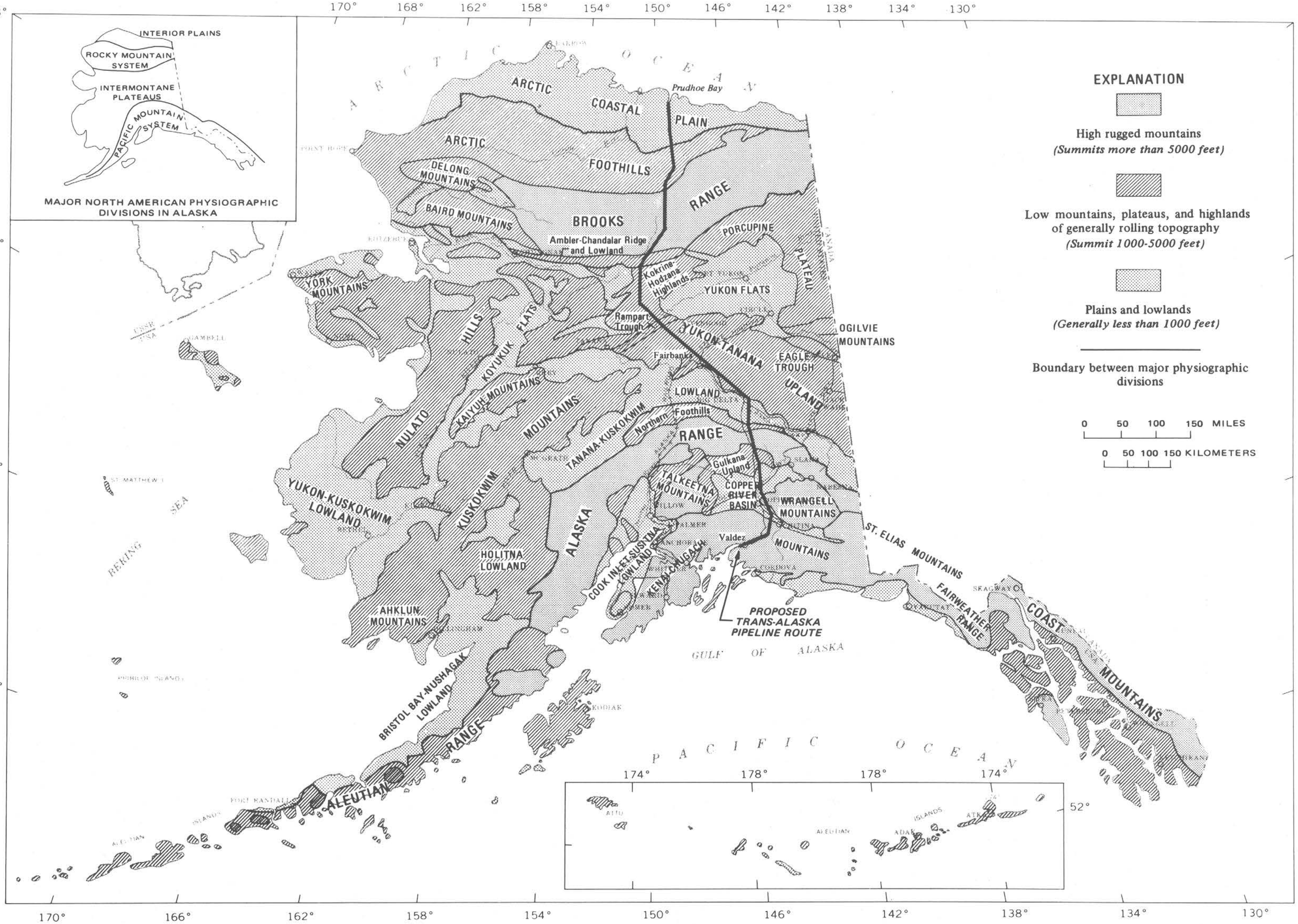

FIGURE 1.—Route of proposed oil-pipeline system. Modified from Wahrhaftig (1964, pl. 1).

ment and to avoid or minimize damage from current and future human development.

The Arctic is as yet practically untouched by modern industrial society, and detrimental effects can and should be avoided. If humans are to develop the resources of the Arctic, then they must choose from all the methods of exploration, extraction, and transportation available those that will cause the least environmental damage. The choice must therefore be based on predictions of the consequences to the environment of the various alternative methods. Environmental impact analysis is the process by which these predictions are made.

In addition to these social and philosophical reasons, industry has imposed on itself reasons for predictive analysis relating to the economic advantages of safe operation and of minimization of capital construction and of operating and maintenance costs. These analyses have for many years been an element in decision making by the pipeline and other industries, but it is now becoming clear that there are economic and social advantages in demonstrating that industry has a proper and positive concern for the environment and in particular for the effects that petroleum development, petroleum transportation, and their complex interactions have on the many facets of the environment. As the people of the United States continue to become more environmentally conscious, it will be advantageous for the oil industry to establish and maintain a position of positive environmental consciousness and action.

In the United States the legal requirements for analyzing environmental impact are contained in the National Environmental Policy Act (NEPA) of 1969[1]. The primary purpose of the United States Congress for that enactment was to establish a Federal policy in favor of protecting and restoring the environment. The wording of the act is such that all aspects of man's surroundings are the subject of Federal concern, and the intent is to make environmental considerations a real part of the governmental decision-making process.

The United States' NEPA contains strong directives to Federal agencies to follow this new policy. One section "authorizes and directs that, to the fullest extent possible * * * the policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with" the policy of the act. Another section of the act directs agencies to give "appropriate consideration" to environmental values in all decisions. Other sections relate to existing Federal agency policies and other aspects of environmental impact analysis and consideration in Federal authorizations of different types. Yet another section of the act establishes that Federal agencies must predict the environmental effects of proposed actions and of their alternatives and describe them in an "environmental impact statement" at an appropriate time in the decision-making process so that environmental considerations can be an actual part of that decision-making process. The environmental impact statement (U.S. Federal Task Force on Alaskan Oil Development, 1972) on the proposed trans-Alaska pipeline which provides the background for this paper was prepared in compliance with that section of NEPA.

Although Canada does not have an act comparable to the NEPA of the United States, it is clear that the intentions of the Canadian Government are similar to those of the United States Government in requiring that environmental considerations shall be a part of resource development in arctic regions and that legal requirements will be imposed on any applicants who propose pipeline construction and operation in the Canadian Arctic. Those requirements will include specific points considering the preservation and protection of the environment; therefore, the analysis of the environmental impact of any proposed pipeline system in northern Canada will be required.

There are of course both in the United States and in Canada many other laws and regulations which pertain to the construction and operation of pipeline systems. They are only indirectly related to the analysis of environmental impact and are incorporated in all planning and design of pipeline projects for the Arctic.

European countries do not yet have the legal requirements for pipeline systems based on exclusively environmental factors like those just discussed for the United States and Canada. Nevertheless, there are governmental regulations regarding the design, construction, and operation of pipelines, and those regulations are indirectly related to environmental considerations. The different governmental procedures, regulations, and national codes now existing in Western Europe have been examined in a paper by Watkins (1971). It is impossible from the author's vantage point in the United States to comment on whether environmental impact analysis requirements are

[1] 42 United States Code 4332.

likely to become a part of pipeline regulations in Western Europe in the near future. Also, it is not known to the author whether environmental impact analysis of pipeline systems has been practiced or is being practiced in the Soviet Union (Pryde, 1972).

Although increased attention is being given environmental questions in Europe (Verguèse, 1972), the impression is that environmental impact analysis as discussed in this paper has not been practiced in other parts of the world.

A broader and more important reason for analyzing environmental impact transcends specific legal requirements. People appreciate now as never before that they exist on an earth that has finite limits and tolerances. In the present century laymen and scientists alike have recognized many symptoms of environmental perturbation that cause concern. These symptoms, and the technical prediction abilities now available, can be used to demonstrate that people can inadvertently and adversely affect their total environment. If people are to continue to enjoy a healthy existence on earth, those effects must be minimized. The costs of minimizing must themselves also be minimized and must be assigned economically as well as socially.

Environmental impact analysis is a process that uses existing information, existing symptoms, and prediction techniques to forecast what environmental impact effects will be. The control of adverse environmental impact effects must be based on the best information available, and the best information available is obtained through environmental impact analysis.

ENVIRONMENTAL IMPACT ANALYSIS OF THE TRANS-ALASKA AND TRANS-ALASKA–CANADA PIPELINE SYSTEMS

The components that are essential in an environmental impact analysis (and the interactions between them) are well illustrated in the example of the proposed trans-Alaska pipeline system and its related developments. Environmental impact analysis requires interrelating several components: analytical method, baseline environmental data, impact linkage data, impacting project data, analysts, and coordination (fig. 2). To be applicable to geographically large, technologically complex, and environmentally sensitive projects, the analytical method should be formulated for the specific environmental situation and proposed project at hand. The general case methodology requires (1) systematic description of the environment including identification and classification of its sensitive elements, (2) systematic description of the project that would be doing the impacting including identification and classification of the impacting factors inherent in it, (3) systematic accumulation of information related to linkages between impacting factors and the environment, (4) analysis of the interrelationships between the sensitive environmental elements and the impacting factors (including indirect and secondary feedback-type relations), (5) prediction of the net effects of those relations, and (6) preparation of an environmental impact report describing the results of the impact analysis. All these components and requirements were successfully included in the analysis of the proposed trans-Alaska pipeline. The actual analysis was made by a task force of resource scientists who were assigned the roles of impact analysts for specific resource topics or disciplines.

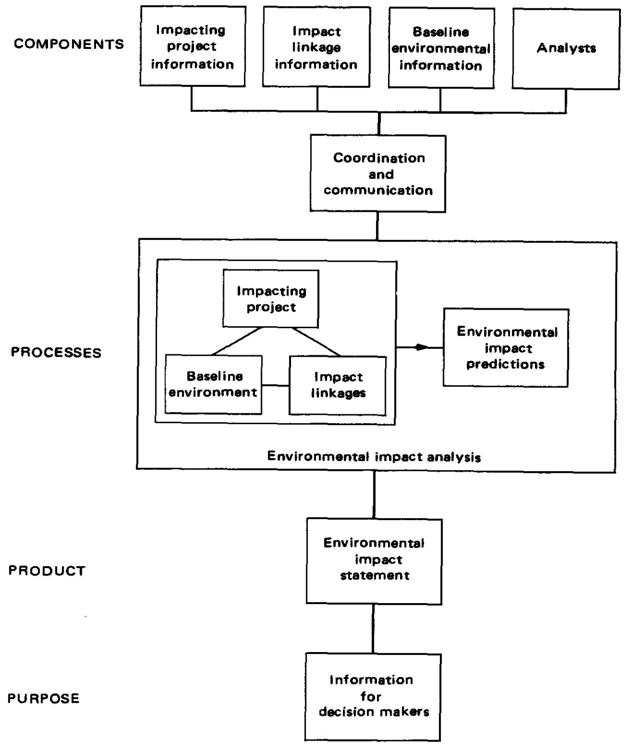

FIGURE 2.—Components and development of environmental impact analysis.

The environmental component and the impacting effects information just referred to could be combined to form an information matrix of specific design for the analysis of the impact of the proposed trans-Alaska pipeline and appurtenant systems. Needless to say, the matrix would be complicated and cumbersome, but it would synoptically depict in simplified fashion which impacting effects would impact on which environmental systems or components of those systems. In this regard, it is pertinent to comment on the approach to environmental impact analysis that is contained in U.S. Geological Survey Circular 645 (Leopold and others, 1971). As discussed later under "Guidelines," the methodology used in the trans-Alaska pipeline analysis rigorously excluded value judgments throughout the process until such judgments were unavoidable; then alternative value framework judgments were presented. The approach described in Circular 645 is quite different in that it presents a nonspecific design approach to impact analysis and in that it admittedly "portrays many value judgments" (p. 1). It was released as a "preliminary effort to fill an interim need" (p. III). The nonspecific design described in that circular may be applicable to many environmental impact situations in which the magnitude and complexity of both the impacting project and of the environmental framework are relatively limited, but it is not well suited to a project with the geographic, ecologic, and engineering complexities of the proposed trans-Alaska pipeline system.

ENVIRONMENT

For the purpose of a comprehensive impact analysis, the environment must be defined and environmental baseline data must be gathered for the total human environment. The total human environment consists of both the biotic and abiotic natural physical systems and the various superimposed socioeconomic systems that are related to people and to their use of the natural physical systems.

Systematic description of the existing environment for impact analysis purposes should accomplish several related purposes: (1) It should inform the reader of the larger environmental framework and ecosystems within which the impact would occur; (2) it should afford the preparer the opportunity to look at a particular topic with the impact potential in mind and to identify sensitive components; (3) it should establish the limitations of the information framework and the degree to which the environmental factors can be quantified; and (4) it should provide reference to more detailed information if it is available.

In accomplishing these purposes for the analysis of the proposed trans-Alaska pipeline, a task force of experts on different environmental topics developed and compiled descriptive baseline information for the proposed pipeline route from Prudhoe Bay to Port Valdez, the marine tanker route from Port Valdez to west-coast ports, and the hypothetical pipeline routes from Prudhoe Bay across Alaska into Canada (fig. 3). These experts were drawn from several Federal agencies including the U.S. Coast Guard, the Environmental Protection Agency, the National Oceanic Survey, the Environmental Data Service, the U.S. Corps of Engineers, the U.S. Geological Survey, the Bureau of Land Management, the Bureau of Outdoor Recreation, the Bureau of Indian Affairs, the Bureau of Sport Fisheries and Wildlife, the National Park Service, and the National Marine Fisheries Service. Other baseline data were obtained from the Institute of Social, Economic, and Government Research at the University of Alaska, the Education Systems Resources Corporation of Arlington, Va., and several departments of the State of Alaska government.

Topics considered under natural physical systems for the environment of the proposed pipeline were physiography and geology, climate, air quality, water resources, vegetation, insects, fish and wildlife, and wilderness; topics considered under superposed socioeconomic systems were land use, population and labor force, the Alaskan Native community, composition of income and employment in Alaska, prices and costs, the oil and gas industry in Alaska, mining, fisheries, agriculture, forestry, electrical power systems, and transportation. For the proposed marine tanker transportation route, topics considered under natural physical systems were coastline and marine geology, climate and weather, physical oceanography, chemical oceanography, marine vegetation, biological oceanography, marine mammals, terrestrial mammals, and birds; under superposed socioeconomic systems the topics were fisheries, recreation, and marine transportation.

IMPACTING PROJECT

To evaluate the impact on the environment, the analysts must know what will cause it, how it will occur, and what it will be in both its primary and secondary manifestations. To facilitate analysis the project that will cause the impact should be presented systematically in a project description which has already been reviewed for technical

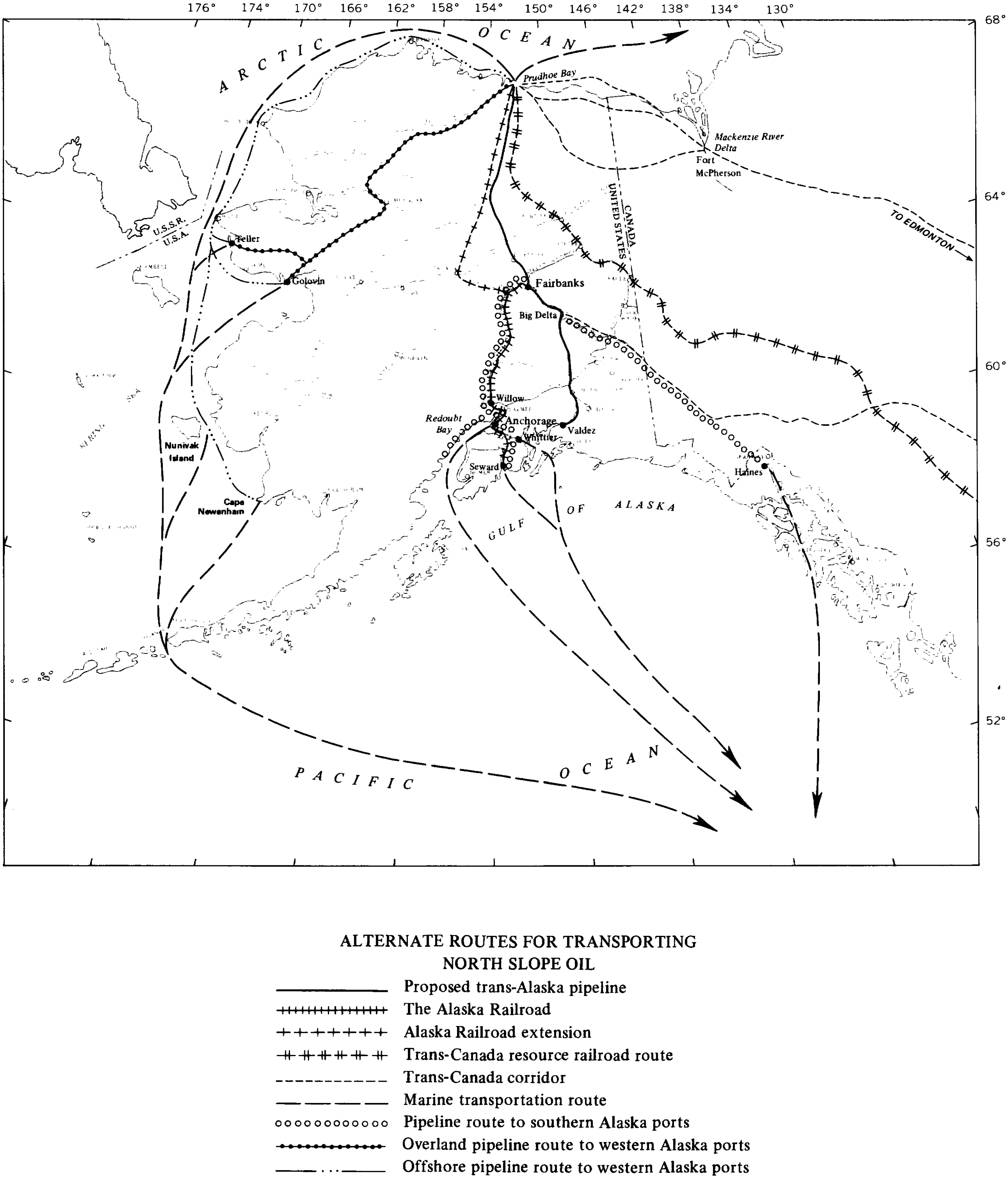

FIGURE 3.—Alaska and northwestern Canada showing alternate routes for transporting North Slope oil.

adequacy, agreement with specifications, and conformance with good environmental practice.

For the proposed trans-Alaska pipeline project, the Alyeska Pipeline Service Company prepared two project descriptions, one covering the proposed pipeline system and related structures and one covering the proposed tanker transport system that would connect the terminus of the pipeline with destination ports. The descriptions were reviewed by ad hoc review groups, and the results of those reviews transmitted to the impact analysts and to the company. Following receipt of those reviews, Alyeska provided supplementary project description material which was also used by the impact analysts. The State of Alaska in cooperation with the Alyeska Pipeline Service Company prepared a description of the probable physical developments that would occur in the oil-field area.

Inasmuch as no proposal describing a specific gas transportation system had been received by the Department of the Interior, it was not certain what route or type of system would eventually be proposed. Accordingly, it was necessary to evaluate the impact of four hypothetical gas-pipeline routes: (1) Prudhoe Bay along the Arctic Slope to near the Mackenzie River Delta and on to Fort McPherson and south to Edmonton, (2) Prudhoe Bay across the Brooks Range to Fort McPherson and south to Edmonton, (3) Prudhoe Bay to Port Valdez along the route proposed for the Alyeska oil-pipeline system, and (4) Prudhoe Bay to Big Delta and east to Edmonton.

IDENTIFICATION OF IMPACTING EFFECTS

Just as systematic examination and description of the environment is needed to identify sensitive environmental components, systematic examination of the impacting project is needed to identify, classify, and quantify as much as possible its impacting effects. The review and evaluation of the project description should attempt to classify those effects in terms of their predictability: some effects will be unavoidable and therefore predictable; others will be probabilistic and therefore predictable only statistically, perhaps by comparison with performance records from similar projects. The evaluation should also classify the impacting effects by their time of occurrence, by whether they are direct or indirect, and by whether they are primary, secondary, or tertiary.

The project descriptions of the proposed trans-Alaska pipeline system and associated developments were analyzed to identify and classify the impacting effects that would modify the existing environment. In all cases the unavoidable impact effects were differentiated from the threatened environmental impact effects (defined as effects with a probability of occurrence of less than 1). The effects during the construction, operation, and postoperation phases were differentiated from each other, as were direct and indirect effects. This was done first for primary impacting effects, and a similar process was carried out for secondary impacting effects; where applicable, tertiary impacting effects were also considered.

Within this complicated framework of distribution of effects were considered such primary and secondary effects as those listed subsequently.

Primary and secondary impacting effects associated with proposed trans-Alaska hot-oil pipeline, Arctic gas pipelines, and proposed tanker system

A. Primary effects associated with arctic pipelines:
1. Disturbance of ground
2. Disturbance of water (including treated effluent discharge into water)
3. Disturbance of air (including waste discharged to air and noise)
4. Disturbance of vegetation
5. Solid waste accumulation
6. Commitment of physical space to pipeline system and construction activities
7. Increased employment
8. Increased utilization of invested capital
9. Disturbance of fish and wildlife
10. Barrier effects on fish and wildlife
11. Scenery modification (including erosional effects)
12. Wilderness intrusion
13. Heat transmitted to or from the ground
14. Heat transmitted to or from water
15. Heat transmitted to or from air
16. Heat to or from vegetation
17. Moisture to air
18. Moisture to vegetation
19. Extraction of oil and gas
20. Bypassed sewage to water
21. Man-caused fires
22. Accidents that would amplify unavoidable impact effects
23. Small oil losses to the ground, water, and vegetation
24. Oil spills affecting marine waters
25. Oil spills affecting freshwater lakes and drainages
26. Oil spills affecting ground and vegetation
27. Oil spills affecting any combination of the foregoing

B. Secondary effects associated with arctic pipelines:
1. Thermokarst development
2. Physical habitat loss for wildlife
3. Restriction of wildlife movements
4. Effects on sports, subsistence, and commercial fisheries
5. Effects on recreational resources
6. Changes in population, economy, and demands on public services in various communities, including Native communities, and in Native populations and economies
7. Development of ice fog and its effect on transportation
8. Effects on mineral resource exploration

C. Primary effects associated with tanker system:
1. Treated ballast water into Port Valdez
2. Vessel frequency in Port Valdez, Prince William Sound, open ocean, Puget Sound, San Francisco Bay, southern California waters, and other ports
3. Oil spills in any of those places

D. Secondary effects associated with tanker system:
   1. Effects on sports and commercial fisheries
   2. Effects on recreational resources
   3. Effects on population in Valdez and other communities

IMPACT LINKAGE INFORMATION

In addition to the baseline environmental and project impact effect data, it is necessary to compile data that pertain to the linkages or paths between and within various kinds of impacting effects and the various environmental topics. The linkages are of many kinds and types. They include all the information needed to actually predict an environmental impact other than the baseline environmental information and project information.

The following example drawn from the Alaska pipeline impact analysis illustrates what is meant by linkage data: Baseline information is available on the distribution of salmon and herring (at various life stages) in time and space in the Port Valdez–Valdez Arm area adjacent to Prince William Sound. Project information provided by Alyeska Pipeline Service Company indicates an estimated 2.4 to 26 barrels of oil per day would be introduced from a ballast-treatment facility into the waters of Port Valdez at a point 100 feet beneath the surface in a concentration intended not to exceed 10 parts per million. The linkage data are those needed to define the spatial and temporal paths that the effluent will take in the dynamic hydroenvironment, the changes it will cause en route in the water's chemical and physical properties, and the effects that the changed water will have on any given salmon or herring resource population at a specific time and place. Linkage data therefore in this case depend on hydrographic information that is properly part of the baseline environment description and also include knowledge of how different concentrations of different hydrocarbons in the water affect the fish population at different life stages.

In the analytical process related to the trans-Alaska pipeline proposal, the compilation of linkage data accompanied compilation of the baseline environmental data and was included both with the baseline data and with the impact analysis results. Where there were conflicting data, the analysts considered all in making the analysis and preparing the results of their analysis.

The limitations on the impact linkage data were the greatest problem encountered in the impact analysis. In many cases the complicated pathways and linkages that would exist between the project and the environment have not yet been studied to the point that predictions can be made with confidence. In such cases the analysts simply stated that rigorous prediction was not possible.

ANALYSTS AND THE ANALYSIS

Proper execution of an environmental impact analysis depends in a major way on the impartiality of the analysts. Regardless of the actual process used, including the use of predictive mathematical or simulation models, the analytical process is sensitive to the abilities and interests of those responsible for evaluating the interaction of the impacting project and the environment. At the present time the state of the art is such that the actual prediction process is likely to involve subjective steps requiring the judgment of the analyst.

Unfortunately, the educational traditions and occupational roles of scientists and technicians do not prepare them for dispassionate analysis of the type required. Resource scientists typically acquire and maintain strong conservation or development biases that reflect the customary work of their disciplines. Engineers and technicians normally adhere to strong developmental biases. The environmental impact analyst, to arrive at a prediction of impact, must discard prior conviction in favor of careful, thorough, systematic, and objective evaluation.

An example illustrates the problem. A government ornithologist responsible for research on endangered bird species and for enforcement of laws and regulations designed to protect them is given the task of objectively evaluating what will happen to those species if certain endangering transportation developments occur. He immediately faces conflict because the evaluation involves acceptance (for analytical purposes) of events which he has opposed for his entire career. An equally valid hypothetical example can be constructed using a development-oriented mining engineer faced with demonstrating sincere concern for the environment in evaluating the effect of an open-pit mine on the nesting area of an endangered species.

The impact analysis of the proposed trans-Alaska pipeline was made by resource scientists who had been given guidance regarding the analysts' proper function. As they proceeded to determine the type and extent of environmental impact that would occur in their respective fields, they were urged to be as rigorous and objective as possible and to utilize fully all available information. There undoubtedly were minor problems in the impact analysis of the proposed pipeline that arose from conflicts the analysts felt between the bias of traditional roles and the impartiality required in impact analysis.

COORDINATION AND COMMUNICATION

Coordination and communication compose the last essential component in environmental impact analysis. Coordination is needed to insure that all topics are handled in the same systematic way by all the analysts. Because of the intricate way in which an impacting project can produce reaction chains of impact effects, it is extremely important that preliminary results of analyses be communicated rapidly and fully from one analyst to another. This communication is facilitated by the awareness of all analysts that the results of others may have a direct effect on the analysis that they themselves are making. Careful attention is required to devise a system that provides this communication and that also generates the kind of information needed at the proper time for use of others involved in the analytical process.

Coordination within the impact analysis task force for the proposed trans-Alaska pipeline was accomplished by a core group of five persons including the chairman. Members of the core group worked closely in providing guidance and information to the individual analysts.

A principal effort was to insure that developments from one analysis that might bear on another were communicated rapidly; the draft material was circulated completely, insofar as possible, to all analysts, and all suggestions made by other analysts, the chairman, and the core group were considered before preparing the final draft of the impact statement. This procedure of replicate internal review results in a final report whose parts are the work of individual analysts and not the work or interpretation of the task force chairman or the core group.

GUIDELINES

Environmental impact analysis requires both philosophical and technical/analytical guidelines. If an analysis and the report of the analysis are to be scientifically, technically, and legally defensible, they must be prepared to the highest standards of objective scientific inquiry. Any attempts to bias the results of an environmental impact analysis cannot escape the notice of careful evaluators of the results.

Inclusion of objective environmental impact analysis information in any complex decision framework adds one more element that possibly conflicts with other elements in the framework. The decision makers of today are (or should be) prepared to evaluate such conflicting elements by applying their values in such a way as to produce a politically, socially, economically, and environmentally just decision. If an impact analysis is to provide this objective information to the decision makers, then the analysts and the analytical process should function in the traditional scientific way.

The technical and analytical guidelines established for any impact analysis should reflect these philosophical points. They should place a high degree of responsibility on the individual analyst for the assembly and compilation of pertinent environmental material and for the understanding of pertinent impacting effects. Similar responsibility exists for preparation of an objective report concerning the results of the impact analysis. Specific guidelines given to the analysts should facilitate preparation of their material in format compatible with that required by any existing laws and suitable for use in communicating with other analysts during the environmental impact analysis process.

A specific guideline worth emphasizing is that, insofar as is possible, value-judgment factors should be omitted from environmental impact analysis; when omission is impossible the specific value framework used should be specified. This is the only way of assuring that the values exercised in the decision are the values of the decision makers rather than the values of those who prepared the environmental impact statement. A related guideline of utmost importance to the impact analysis process is for the analysts to recognize fully and completely that <u>they</u> are not to decide the issue.

This discussion of environmental impact analysis would be incomplete without mention of the extremely critical relation between the impact analysis and the "decision point." Stated otherwise, what type and scope of environmental analysis can and should be made at the different "decision points" in the overall decision-making process that accompanies evolution of a project? The information available about a pipeline or any other project varies with time, from a relatively low level in the conceptual stage to a high level in the final construction and operation stages. Depending on the project, its location, the types of impacts possible, and other factors, the pertinent environmental information may or may not follow a similar path. The determination that the available environmental information is adequate in scope and quantity to constitute an element in the decision process depends mainly on the value framework of those responsible for the decision. As environmental awareness and conscience develop, certain critical elements of environmental information should become acknowledged as requirements for just decisions, in the same way that predicted cost and profit data are now universally accepted as critical factors in the analysis of economic feasibility.

In the case of the proposed trans-Alaska pipeline, policymakers in the Department of the Interior decided that the available environmental information was adequate for impact analysis. This was determined before the environmental data had been compiled, and it is therefore questionable to what extent the amount of environmental data actually available influenced the decision to proceed. In retrospect, however, the baseline environmental information available at the start of the impact analysis was approximately comparable in quantity and quality to data available on the proposed pipeline project.

In several ways the completion of the impact analysis of the proposed trans-Alaska pipeline represents a successful endeavor. Because there was no precedent for the analysis, it was necessary to design the procedures to be used, find and assemble the people to work on it, and establish the philosophical and technical guidelines that would result in a scientifically sound product. The methods used in the analysis and in the preparation of the report were rigorous and objective, the analytical group was independent of exterior influence, and the results are a milestone in the developing science of environmental impact analysis.

MAIN TYPES OF IMPACT PREDICTED BY THE ANALYSIS

The analysis indicated that environmental impact would result from (1) the construction, operation, and maintenance of the proposed oil-pipeline system, including the accompanying highway north of the Yukon River, and of a gas transportation system of some kind, (2) from oil field development, and (3) from the operation of the proposed marine tanker system. Because of the scale and nature of the project, the impact would occur on abiotic, biotic, and socioeconomic components of the human environment far beyond the relatively small area (940 sq. mi. out of 572,000 sq. mi. of land area) of Alaska that would be occupied by the oil-pipeline system and the oil field. The impact paths between the project itself and the affected parts of the environment would be of varying complexity and length and would involve linkage factors that are not all well known.

Of the impact effects that would occur, some, like those associated with wilderness intrusion and public access north of the Yukon River, could be considered either beneficial or adverse depending on the value framework used. Some of the effects on socioeconomic parts of the environment would be classified as beneficial by most persons. Most of the other impact effects would in some way alter the existing environment in a way that was not demonstrably beneficial and would in that sense be adverse. Such effects would occur both on natural physical systems and on the superposed socioeconomic systems.

Some impact effects are unavoidable and can be evaluated with a degree of certainty. Others could result from the occurrence of a threatened event of some kind which would impact the oil or gas transportation systems. These threatened impact effects cannot be evaluated with comparable certainty.

The principal unavoidable effects would be (1) disturbances of terrain, fish and wildlife habitat, and human environs during construction, operation, and maintenance of the oil pipeline, the highway north of the Yukon River, the oil field, and the gas pipeline that would probably follow, (2) the effects of the discharge of effluent from the tanker-ballast-treatment facility into Port Valdez and of some indeterminate amount of oil released into the ocean from tank-cleaning operations at sea, and (3) effects associated with increased human pressures of all kinds on the environment. Other unavoidable effects would be those related to increased State and Native corporation revenues, accelerated cultural change of the Native population, and extraction of the oil and gas resource.

Changes in stable terrain caused by construction and maintenance procedures could produce rapid and unexpected effects, including slope failure, modification of surface drainage, accelerated erosion and deposition, and other disturbances as a result of the permafrost thawing that would follow destruction of the natural insulating properties of the tundra. Placement of gravel pads and berms would especially affect surface drainage. The excavation of borrow materials and placement of the pipeline ditch in and near flood plains and streambeds would also cause changes in stream erosion and deposition. About 83 million cubic yards of construction material, mostly gravel, would be required for the oil pipeline. The general noise, commotion, and destruction of local habitat could cause many species of wildlife to leave an area amounting to about 60 square miles.

Socioeconomic effects during construction would include accelerated inflation, increased pressures on existing communities for accomodations and public services, and job opportunities for perhaps 25,000 persons at peak times (including multiplier effects); unemployment in Alaska, however, would continue to be relatively high.

The main disturbances during operation would be (1) thawing in permafrost leading to possible foundation instability and differential settlement, (2) some barrier effects of aboveground oil-pipeline sections on large mammal (especially caribou) migrations in the Brooks Range, Arctic Coastal Plain, and Copper River Basin areas, and similar effects of any aboveground sections of gas pipeline that would eventually be built, and (3) adverse but unquantifiable effects on the marine ecosystem of Port Valdez and perhaps Valdez Arm and Prince William Sound proper from the discharge of an estimated 2.4 to 26 barrels of oil per day from the ballast-treatment facility and on the marine ecosystem in general from discharge of an indeterminate amount of oil from tank-cleaning operations at sea. These last effects would in turn affect the fishing industry to some unquantifiable extent.

Other main operational effects would include (1) the gradual conversion of about 880 square miles of the North Slope wildlife habitat to an area with widely spaced drilling pads, roads, pipelines, and other structures, with the accompanying adverse effects on the tundra ecosystem, (2) the many diverse effects on wilderness, recreational resources (including hunting and fishing), and general land-use patterns that would result from increased public access to the now relatively inaccessible region north of the Yukon River, (3) acceleration of the cultural change process that is already underway among Alaskan Natives and some adverse modification of local Native subsistence-resource base as a result of secondary effects, and (4) additional state revenues of about $300 million per year and subsequent expenditure of those revenues for public works and activities throughout Alaska. Immediately after the end of construction, unemployment would probably increase.

The main threatened environmental effects would all be related to unintentional oil loss from the pipeline, from tankers, or in the oil field. Oil losses from the pipeline could be caused by direct or indirect effects of earthquakes, destructive sea waves, slope failure caused by natural or artificial processes, thaw-plug instability (in permafrost), differential settlement of permafrost terrain, and bed scour and bank erosion at stream crossings. Any of these processes could occur at some place along the route of the proposed pipeline. Oil loss from tankers could be caused by accidents during transfer operations at Valdez and at destination ports like Puget Sound, San Francisco Bay, and Los Angeles, and by tanker or ship casualties resulting from collision, grounding, ramming, or other causes along the tanker routes.

The potential oil loss from pipeline failure cannot be evaluated because of the many variables involved, but perfect no-spill performance would be unlikely during the lifetime of the pipeline. Various models of oil loss from the tanker system indicate that an average of 1.6 to 6.0 barrels per day could be lost from the whole system during transfer operations and an average of 384 barrels per day or about 140,000 barrels per "average" year could be lost from tanker casualties. This modeled loss would occur in incidents of undetermined size at unknown intervals and at unknown locations. This is considered to be a maximum or "worst case" casualty discharge volume.

Oil spilled from the pipeline as a consequence of one of the threats mentioned could, depending on location, volume, time of year, and other factors, result in adverse effects on all the biota involved. Not all the linkages and impact paths are known, but vegetation, waterfowl, and freshwater fisheries could all be affected and then affect Native subsistence use to an unquantifiable extent.

Oil spilled in tanker casualties or transfer operations would affect the marine ecosystem to an extent that would be determined by many variable factors. The salmon and other fishery resources of Prince William Sound would be especially vulnerable to such spills. Over the long term, however, persistent low-level discharge from the ballast-treatment facility and tank-cleaning operations at sea could have a greater adverse effect than short-lived larger spills.

The probable eventual construction and maintenance of a gas pipeline would, if it were not in the oil-pipeline corridor, result in a separate corridor with many of the same effects described for the proposed oil-pipeline corridor. Those effects and those impacts on the environment would be in addition to those predicted for the proposed oil-pipeline system.

ANALYSIS AND COMPARISON OF ALTERNATIVES

The environmental impact analysis also included consideration of various alternatives to the oil transportation system proposed. The three main types of alternatives examined were those available to the Secretary of the Interior, those concerning alternative routes and transportation systems, and those concerning energy and policy alternatives. The information regarding energy and policy alternatives was compiled and prepared by a special task force made up of representatives of various Federal agencies.

The alternatives considered available to the Secretary of the Interior were granting the permits that had been applied for, denying the permits, or deferring any action. The environmental impact implications of those different actions were examined.

Alternative routes and systems for the transportation of oil included (1) pipelines from Prudhoe Bay to other ice-free ports in southern Alaska such as Redoubt Bay, Whittier, Seward, and Haines, (2) marine transportation systems including ice-breaking and subsurface tankers, (3) both offshore and overland pipelines to terminal ports on the Bering Sea, (4) trans-Alaska–Canada pipelines to Edmonton including coastal offshore and onshore routes to the Mackenzie River Delta, routes inland across the eastern Brooks Range to Fort McPherson, and routes across the central Brooks Range (along the proposed oil-pipeline route) to Fairbanks, Big Delta, and east along Alaska Highway, (5) railroad and highway transportation modes including an Alaska railroad extension from Prudhoe Bay to a southern Alaska port and a new trans-Alaska–Canada railroad route and highway system, and (6) other oil transportation schemes including land, sea, air, and in other energy forms (fig. 3). Some of the alternate oil-pipeline routes that were considered and analyzed are, as noted previously, the same as those routes considered and analyzed for gas pipelines.

The energy and policy alternatives examined were (1) reduction in demand, (2) increased oil imports to the United States, (3) additional production from outer continental shelf and onshore areas, (4) modification of natural gas pricing, (5) nuclear stimulation of natural gas reservoirs, (6) increased use of coal as solid fuel and as source for synthetic fuels, (7) nuclear fuel, (8) synthetic sources, oil shale, tar sands, coal, (9) geothermal power, (10) hydroelectric power, and (11) exotic energy sources and improved efficiency systems.

The analysis of the environmental impact of the alternative trans-Alaska–Canada route and other routes provided information that was used for a comparison between those routes and the proposed trans-Alaska route. This comparison resulted in relative ranking of important impact effects for all the routes. The comparison process included (1) identification of combinations of routes and modes of transportation, (2) identification of specific unavoidable impact effects taking into account the abundance and vulnerability of the resources involved, the length of the route along which they would be affected, and the impact factors that would probably be involved, (3) identification of specific major threatened impact factors, and (4) ranking the different routes against each other on an arbitrary relative-magnitude scale. In the comparison no attempt was made to imply absolute magnitude or to weight any impacts or impact factors in relation to each other.

For the terrestrial environment the unavoidable environmental impacts that were compared included terrain disruption related to oil pipeline, terrain disruption related to terminal, construction material requirements, induced terrain disruption, physical space commitment, surface- and ground-water effects, air-quality effects, vegetation and habitat disruption, and effects on fisheries, on wildlife including birds, on recreation and esthetics, on wilderness, on communities, and on Native culture and subsistence. For the marine environment the unavoidable impacts considered included effects on Alaskan terminal port waters, destination port waters, fisheries, and wildlife including birds. The threatened environmental impact factors that were compared for the terrestrial environment included seismic risk to the pipeline, seismic risk to the terminal, permafrost degradation, slope failure, flooding risk, and, for the marine environment, tanker casualties and oil-transfer operations.

Synthesis of the material included in the comparison of the different routes and transportation modes resulted in several conclusions which were reported in the final environmental impact statement: (1) No single generalized oil-pipeline route appeared to be superior in all respects to any other; (2) in comparing the unavoidable impacts upon the terrestrial abiotic systems, it appeared that all the trans-Alaska routes would have less impact than the trans-Alaska–Canada routes; (3) in comparing the unavoidable impacts upon various terrestrial biotic systems, it appeared that the trans-Alaska route to a Bering Sea port would probably have the least impact and the trans-Alaska–Canada coastal route the next lowest impact; (4) in comparing the unavoidable impacts upon socioeconomic systems, it emerged that the trans-Alaska–Bering Sea port route would probably have the least impact and the trans-Alaska–Canada coastal route would be next; (5) in comparing unavoidable impacts on the marine environment, all the trans-Alaska–Canada routes would have less impact than the trans-Alaska routes; (6) in comparing the threatened environmental impact factors for the terrestrial environment, the trans-Alaska–Canada coastal and inland routes were found to pose the least threat; and (7) comparing the threatened environmental impact factors for the marine environment, the trans-Alaska–Canada routes would be lowest because no direct marine transportation of oil would be involved.

It should be kept in mind that different levels of information were available for the proposed Alyeska Pipeline Service Company oil-pipeline system, for the alternate oil transportation systems and routes, and for gas transportation systems and routes. This difference affected the analysis and therefore all the comparisons.

The information in the environmental impact statement and in related documents released as a result of legal action after the final statement established that one of the important environmental questions involved comparison of an overland one-corridor oil- plus gas-pipeline transportation system through Alaska and Canada with a two-corridor system involving an oil pipeline through Alaska connecting to a tanker route and a gas pipeline through Alaska and Canada. Although this question was not considered in detail in the final environmental impact statement, the author believes it is important to reiterate here the pertinent facts available during the final decision process and the conclusions he drew from that information. It is emphasized that different conclusions could be (and were) drawn from the same information by other parties and persons.

Any combination of overland pipeline plus tanker systems or of tanker systems alone would impose the threat of oil pollution on the marine environment. The most important causes would be contamination resulting from intentional oil discharge from a ballast-treatment facility and from possible tank-cleaning operations at sea and from unintentional oil loss during transfer operations and from oil-tanker casualties. LNG (Liquefied Natural Gas) tanker systems would impose some threat of unintentional gas loss resulting from ship casualties. If LNG tankers were operating from the same ports as the oil tankers, they would contribute to increased vessel density and thereby indirectly to oil-tanker casualty frequency.

Overland gas- and oil-pipeline systems would impose the threat of environmental impact from rupture and unintentional loss of oil or gas. The most likely cause of rupture would be earthquakes and their attendant ground effects. The most likely impact from gas-pipeline rupture would be fire that could spread into areas adjacent to the pipeline. The most likely effect of oil-pipeline rupture would be oil lost onto the land and into lakes and streams and the various secondary effects that such loss would cause.

Any overland oil- and gas-pipeline systems would intrude the wilderness and would utilize physical space for the pipeline alinement as well as for camps, pump stations, airfields, and so forth; the accompanying roads would provide access along the pipeline corridors. Access would bring with it increased recreational opportunity and increased human pressures on the wilderness resources.

A combination of oil and gas pipelines in one corridor (not necessarily on a single or contiguous rights-of-way) would localize and restrict these effects and thus require less space, cause less wilderness intrusion, provide less access, have less effect on fish and wildlife habitat, and probably have less overall effect on the migration of large animals.

Based on these considerations and without specifying one or another corridor or transportation mode, it is the author's opinion that one corridor containing both oil and gas pipelines would have less environmental impact and thus incur less environmental cost than would separate corridors.

Considering (1) the threat to the marine environment that any tanker system would impose, (2) the threat that zones of high earthquake frequency and magnitude would impose on pipelines, and (3) the apparent lesser environmental impact of a single corridor as compared with two corridors, it is the author's opinion that environmental impact and cost would be least for a gas- and oil-transportation system that (1) avoided the marine environment, (2) avoided earthquake zones, and (3) placed both oil and gas pipelines in one corridor. The onland trans-Alaska–Canada routes to Fort McPherson and through the Mackenzie Valley to Edmonton would meet these criteria for minimizing environmental impact and would, from that point of view, be preferable. Of the possible onland routes, the inland route across the Brooks Range between Prudhoe Bay and Fort McPherson appears on some grounds to cause the least overall adverse environmental impact.

These conclusions of the author are subject to one additional qualification. To reach market areas, any solely overland oil and gas transportation system ending near Edmonton would have to be extended beyond the geographic limits that were set for the environmental impact analysis and would thus entail additional environmental impact. The extended construction and operation would, however, be entirely in areas now traversed by oil and gas pipelines and no unusual problems would be encountered nor would any new transportation corridors be created.

As noted earlier, other conclusions are possible, and indeed the official conclusion of the U.S. Department of the Interior and of the U.S. Congress was that the environmental costs of a trans-Alaska–Canada hot-oil pipeline would be approximately the same as those of the proposed trans-Alaska hot-oil pipeline.

CONCLUSION

To this point this paper has been concerned mainly with the scientific and analytical aspects of environmental impact analysis and with the impact analysis of the proposed trans-Alaska oil pipeline and its alternatives. This final section examines some human and political aspects of this previously discussed material.

The scientist involved in environmental impact analysis should use the same standards and practices that he uses in scientific work. He is not only responsible for using the best available information and using it in the best possible way, but also for making sure that no personal biases enter the analytical procedure. By keeping impact analysis entirely scientific, it is possible to produce information which provides an objective input to the decision process.

Nevertheless, it is likely that almost all environmental impact analysis will be conducted in situations which are influenced by external pressures. These pressures lead to the imposition of time constraints and to requirements that the analysis be made without significant amounts of additional information that would normally be acquired through extensive research. Although the involved scientist will be affected by these pressures, he will not be absolved of the responsibility of conducting the analysis in a rigorous scientific fashion.

The coordination of an environmental impact analysis and the communication of the results to the decision makers will necessarily involve scientists who are in a supervisory role. The external political and economic factors which often are a major part of the decision makers value framework are likely to be brought to bear directly on those scientists. They therefore have the responsibilities of (1) maintaining the scientific standards of the analytical group against any external pressures and (2) communicating the results of the environmental impact analysis effectively to the decision makers. More and more scientists will have these responsibilities in the future as the world's decision makers require more and better scientific input on questions of critical environmental significance.

The way in which the United States Government received and used the environmental information of the trans-Alaska pipeline impact analysis is a most important part of this story. The results of the analysis were provided to the decision makers in the written final environmental impact statement and in discussions between the policy makers and the core group of the task force that made the impact analysis. Clear documentation of how the results of the environmental impact analysis and other pertinent information were used in the decision is contained in a document[2] released on May 11, 1972, by the Department of the Interior. This document notes that the major considerations involved in the decision on the proposal were (1) United States energy and crude oil posture, (2) national security aspects, (3) choice of market for North Slope oil, (4) the proposal for the trans-Alaska pipeline, (5) alternative methods of transporting North Slope oil, and (6) further deferral of action. Brew and Gryc (1974) analyzed the document in relation to the information contained in the final environmental impact statement.

The decision document concludes that the environmental consequences of either a trans-Alaska or trans-Alaska–Canada oil-pipeline route are acceptable when weighed against the advantages to be derived from the construction. The Department of the Interior concluded that the Alyeska proposal was acceptable. Similar conclusions are contained in the testimony of Secretary of Interior Morton before the Joint Economic Committee of Congress (U.S. Congress, 1972).

The conflict between environmental values and resource development values that the trans-Alaska pipeline exemplifies demonstrates the continuing need for research on impact analysis and for environmental impact analysis as an essential early component in industrial and governmental decision making and also demonstrates that the scientist can and must interact with the engineer and with those in decision-making roles if the critical human goal of compatibility of environmental and resource-developmental factors is to be achieved.

[2] "Applications for pipeline right-of-way and ancillary land uses, Prudhoe Bay to Valdez, Alaska," and "Application by State of Alaska for right-of-way for highway—Statement of reasons for approval." U.S. Dept. Interior, Office of Communications, Washington, D.C., May 11, 1972.

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