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THE ENVIRONMENT OF ALASKA:
ANALYSIS OF THE IMPACT OF POTENTIAL DEVELOPMENT

**THE ENVIRONMENT OF ALASKA:
ANALYSIS OF THE IMPACT OF POTENTIAL DEVELOPMENT**

**Prepared in Conjunction with a Land Systems Study for the
JOINT FEDERAL—STATE LAND USE PLANNING
COMMISSION FOR ALASKA**

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SECTION I

INTRODUCTION

A. BACKGROUND

The Joint Federal—State Land Use Planning Commission for Alaska was established in accordance with Section 17 of the Alaska Native Claims Settlement Act (Public Law 92-203) and by act of the State of Alaska (Alaska Statute 41.40.010). The Commission is comprised of ten members representing both federal and state governments and assisted by a staff which includes planners, economists, lawyers, and resource specialists.

In order to provide the Commission with a data base on the resources of Alaska, a Resource Planning Team was assembled in July 1972 to prepare a statewide inventory of natural and man-made resources. This inventory was published in July 1974 as the *Alaska Resources Inventory*, together with a summary entitled *Resources of Alaska, A Regional Summary*. In addition, the Resource Planning Team prepared a set of maps and overlays at a scale of 1:250,000 depicting the various physical, biological, and human resources of the state. These resource documents have served a wide range of needs and have provided the Commission with the information required to carry out their mandate to make recommendations as to the disposition of various state and federal lands and to assist Alaska natives in their land selection process. In addition, the Arctic Environmental Information and Data Center (AEIDC) has undertaken a program to prepare a series of regional documents entitled *Alaska Regional Profiles*, which further describe the environment of the state.

Under its current research program, the Commission is involved in a series of studies and issue analyses directed at developing policies and recommendations for inclusion in a final report to federal and state administrations, to Congress, and to the Alaska Legislature.

It is the Commission's objective that the recommendations embodied in this final report will provide direction for developing a comprehensive land management system for management of Alaska's lands and resources. Included in the report will be recommendations on procedural changes needed to improve coordination among land owners and government agencies regulating land use. These recommended procedures will be designed to avoid conflicts among land users and will include proposed laws, policies, and programs.

In order to achieve these goals and establish the necessary procedures for land management, the Commission has begun a series of three interrelated studies on land systems, socioeconomics, and management systems. The land systems study, which is the subject of the initial work program, includes four major elements directed at developing alternative land use policies and strategies which reflect the sensitivity and interdependence of major ecosystems in the state. The land systems study program will result in the production of four major reports. The focus of each of the program elements is briefly described as follows:

- Element A, Resource Inventory Analysis — Includes a critical analysis of the resource information already developed by the Commission, recommendations on future additional research, information requirements needed to improve the utility of the inventory, and recommendations for maintaining and updating the inventory.
- Element B, Ecosystems Analysis — Includes an identification and analysis of the constraints of, and opportunities afforded by, the lands of Alaska, viewed in the context of its various physical and biological environmental systems.
- Element C, Impact Analysis — Involves the analysis of the impact of man's actions on the environment using three levels of activity, ranging from basic engineering actions through cumulative actions, to determine the threshold of sensitivity of various ecosystems within the state.
- Element D, High Value/Critical Area Identification — Involves an identification of areas within the state which are of high value or critical importance with respect to the natural and physical resources of the state.

The first three elements of the land systems study have been undertaken by the Commission in consultation with a team of resource specialists, planners, environmental scientists, and lawyers. Element D is to be accomplished by the Commission and its staff, utilizing information and criteria developed in conjunction with the work program.

The results of the initial land systems study program (Element A) are presented in three volumes:

- *Environmental Resource Information: Status, Use, Needs, and Recommendations*
- *Environmental Resource Information: Status, Use, Needs, and Recommendations — A Summary*
- *Detailed Evaluation of the Alaska Resources Inventory*

The results of the second land systems study program (Element B) are also contained in three reports:

- *Natural Hazards in the Alaska Environment: Processes and Effects*
- *The Environment of Alaska: Resource Specific Quantification*
- *The Environment of Alaska: Analysis of Physical and Biological Determinants*

The final work program, undertaken by the consulting team, is presented in this report, entitled *The Environment of Alaska: Analysis of the Impact of Potential Development*. This final study relies heavily on the information developed in the Element B analyses and should be viewed as an extension of the ecosystems documents. In the traditional method of impact statement preparation, the key elements in the evaluation process are the discussions of the

- Existing conditions
- Proposed action
- Impact of the action on the existing environment

The "existing conditions" are described in the report entitled *The Environment of Alaska: Analysis of the Physical and Biological Determinants*. In this study, the major environmental processes associated with the terrestrial and aquatic environments of Alaska are described. Included in this discussion are the biotic and abiotic factors of soil formation; hydrology; meteorology; production, energy flow, and food webs; succession; nutrient cycles; and interactions of these factors. Application of these environmental processes to specific physiographic areas of the state is then presented. In all, a total of 14 analysis regions were evaluated by their various physiographic units, which included coastal lowlands, coastal uplands, interior lowlands, interior uplands, and steep mountains.

Using this information as the baseline for analysis, this document presents a series of potential "proposed actions" and overlays them on the various environments described. How such human activities affect the environment or alter the baseline can then be presented in the "impact evaluation." The methods and objectives employed in support of this impact evaluation process are described in the following subsection.

B. OBJECTIVES AND SCOPE

The major objective which governs the work program for this phase of the Alaska land systems study is to provide the Joint Federal—State Land Use Planning Commission for Alaska with information on the probable environmental impacts associated with human use and development of the state's land and resources. The following objectives are more specifically detailed and have been designed to support the major objective.

- To determine and select, in conjunction with the Commission, those human activities to be analyzed, including basic engineering actions, combinations of actions, and aggregate actions
- To analyze the selected actions in terms of the major activities generated and the resources required to carry out the actions
- To array the selected actions against the physiographic units or ecosystems described in the Element B report, *The Environment of Alaska: Analysis of Physical and Biological Determinants*, and determine the expected degree of occurrence based on the existing natural resources
- To discuss the natural and physical systems or components which could be altered by an action including the effects on soils, air quality, noise environment, water quality, terrestrial and aquatic ecosystems, and the interactions of such impacts
- To summarize the impacts associated with each level of activity or type of action and develop a matrix which identifies the degree of impact on each physiographic unit

The initial task involved selection of the actions for impact analysis. In conjunction with the Commission staff, the following activities were selected:

Level I — Basic Engineering Actions

- Clearing and grubbing
- Excavation
- Construction fill on land
- Foundation construction
- Construction fill on water and wetlands
- Dredging
- Drilling for water

Level II — Combinations of Engineering Actions

- Exploration for oil and gas
- Road construction
- Dam construction
- Exploration and recovery of hard rock minerals (mining)
- Commercial logging
- Agriculture (farming for production crops)

Level III — Aggregate Actions

- Community development (200 homes)
- Recreational development
- Natural resource development complex

These activities were selected on the basis of the likelihood of their future occurrence throughout the state and on the basis that they were representative of a wide range of resource uses which might result in varying degrees of impact.

The following sections of this report are designed to systematically address the objectives established. Section II deals with the general nature of the various impacts, how they are measured, how they are modeled or evaluated, and what activities alter their quality or occurrence. The environmental aspects considered (air, water, noise, etc.) are presented in a manner that permits their later application to the specific actions being analyzed.

Section III of the report is basically a constraint analysis which is designed to project the potential occurrence of the various actions throughout the state. The purpose of this analysis was two-fold: First, it eliminated from consideration those actions which would not be expected to occur due to the absence of a required resource or due to the presence of physical or natural conditions which would preclude development of a resource (e.g., no arable land in the coastal lowlands of the Arctic would result in its being precluded from the analysis of agricultural activity). Second, it highlights those areas of the state which are most likely to experience certain types of development due to the amount and extent of the natural conditions required to carry out an action.

Section IV reflects the final step in the analysis procedure. Each of the activities or actions is described, the resources required to complete the action discussed, the general permits which might be required specified, and the impacts set forth. Following this discussion, a matrix is presented which references the environmental effects of the action by physiographic unit and three levels of severity of impacts with respect to each unit.

The results of this impact analysis, in conjunction with the previous studies accomplished under the total land systems study, provide the Commission with a substantial body of information which can be used to systematically evaluate future land management activities based on the natural environmental character of the land.

SECTION II

GENERAL IMPACTS

The purpose of this section is to identify the general impacts of human-related development actions as applied to the following environmental elements:

- Air quality
- Noise
- Water quality
- Terrestrial biology
- Aquatic biology
- Soils
- Environmental interactions

These environmental considerations are discussed in terms of why they are particularly important, how they are measured or evaluated, how changes might affect the selected natural or physical environment, and the resulting severity or extent of such impacts.

Such a discussion is designed to provide a broad framework for the subsequent analysis of specific actions contained in Section IV of this report. Furthermore, the matrix evaluation employed in the analysis of each selected action is keyed to this general impact identification. This two-level analysis technique makes it possible for the reader to understand the environmental implications of each action.

A. AIR QUALITY

It is important to distinguish between the different regions of Alaska based on some determination of the potential for air pollution problems. In those regions where the meteorological conditions are particularly suited to producing air pollution problems, development of all kinds should be scrutinized carefully. In this scheme of analysis, the meteorological potential, existing air pollution problems, and impacts of the proposed action are determined separately. A determination of severe in all three should indicate real problems. A determination of severe in two out of three should require more careful analysis. Each of these characteristics is somewhat site-dependent and also dependent on the time of year of operations.

1. Air Pollution Potential

In Holzworth (1972), an air pollution potential for the contiguous United States was developed. The present study has not been of the scope to do a similar analysis for the state of Alaska. Due to the limited number of stations sampling the meteorological conditions of the upper atmosphere and the predominance of the few stations that do sample to the lowlands, such a study would be biased or require a number of assumptions about the influence of topography and the results.

Holzworth (1972) hypothesized two city sizes on which to base his potential. In this analysis, only meteorological conditions are used to determine the air pollution potential. A meteorological potential has limitations: (a) it must be inferred from a very few observing stations and extrapolated to the rest of a region; (b) it is time-dependent so that averages over a month's data may not reflect the shorter duration bad conditions during the month; (c) the potential is seasonal and so must reflect "worst case" problems rather than annual averages.

January 1975 in downtown Anchorage is an example of the limitations of this approach. The average wind speed for the month was 5.22 knots. On 17 days out of the month the average was lower than that, and on 4 days of the month the average was less than 2 knots. On 7 days of the month, the national and state ambient air quality standards for carbon monoxide (8-hour average) were violated. Furthermore, on the worst day (January 17) the wind speed as measured at the international airport averaged 8.7 knots with indication of Chugach winds coming down Turnagain Arm, leaving the downtown area in a different wind regime with much lower winds. These localized and short-duration features must be considered in a site-by-site analysis for each potential action.

For the purposes of this analysis, it will be assumed that severe air pollution potential is associated with (a) surface temperature inversions persisting into the afternoon for more than 60 percent of the time in any month, (b) wind speeds averaged over a month less than 6 knots, and (c) less than 5 days with 0.01 inch of precipitation for the same months as in (a). Moderate air pollution potential is assumed to apply to adjacent physiographic units or to those areas experiencing surface-based inversions extending into the afternoon more than 35 percent of the time with wind speeds less than 8 knots, and less than 5 days per month with precipitation.

2. Existing Air Quality Problems

Pollution problems already exist in the state of Alaska. These must be taken into consideration in planning decisions for future development. The determination that a problem exists is based on the state and national ambient air quality standards summarized

in Table II-I. These standards are based on health effects (the primary standards) and on welfare effects such as soiling and effects on vegetation (secondary standards).

TABLE II-I. AMBIENT AIR QUALITY STANDARDS

	National		State of Alaska	Notes
	Primary	Secondary		
Suspended Particulates				
Annual geometric mean	75 $\mu\text{g}/\text{m}^3$	60 $\mu\text{g}/\text{m}^3$	60 $\mu\text{g}/\text{m}^3$	1
24-hour average	260 $\mu\text{g}/\text{m}^3$	150 $\mu\text{g}/\text{m}^3$	150 $\mu\text{g}/\text{m}^3$	2
Sulfur Dioxide				
Annual average	80 $\mu\text{g}/\text{m}^3$		80 $\mu\text{g}/\text{m}^3$	1
24-hour average	365 $\mu\text{g}/\text{m}^3$		365 $\mu\text{g}/\text{m}^3$	2
3-hour average		1300 $\mu\text{g}/\text{m}^3$	1300 $\mu\text{g}/\text{m}^3$	2
Carbon Monoxide				
8-hour average	10 mg/m^3	10 mg/m^3	10 mg/m^3	2
1-hour average	40 mg/m^3	10 mg/m^3	40 mg/m^3	2
Photochemical Oxidants				
1-hour average	160 $\mu\text{g}/\text{m}^3$	160 $\mu\text{g}/\text{m}^3$	160 $\mu\text{g}/\text{m}^3$	2
Nitrogen Dioxide				
Annual average	100 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$	1
Reduced Sulfur Compounds				
30-minute maximum	none	none	50 $\mu\text{g}/\text{m}^3$	2

$\mu\text{g}/\text{m}^3$ — micrograms per cubic meter

mg/m^3 — milligrams per cubic meter

1. Never to be exceeded

2. Not to be exceeded more than once per year

The state of Alaska is divided into four air quality regions, as shown in Figure 2-1. Most of the population of the state and most of the pollution sources are centered in two areas — Anchorage and Fairbanks. To best characterize existing air pollution problems, the standards, health effects, existing sources, existing problems, and meteorological effects are discussed for each pollutant.

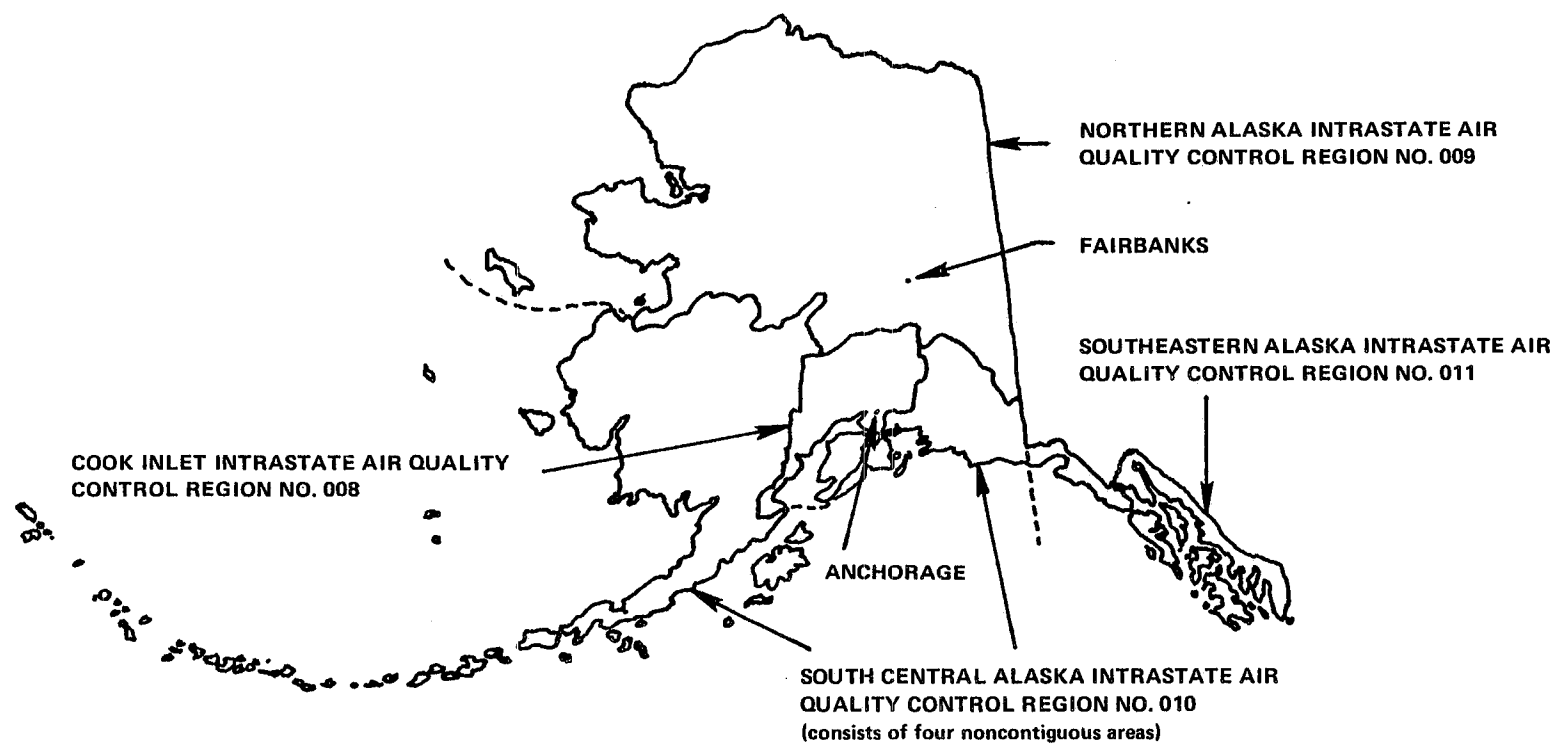
a. Particulates

Small discrete masses of solid or liquid matter dispersed in the atmosphere, especially those of 1 micron or less in diameter, are associated with a variety of adverse effects on public health and welfare. Particulate matter in the respiratory tract may produce injury by itself, or it may act in conjunction with gases to increase the effect on the body. Small particles suspended in the air are chiefly responsible for reduced visibility. Soiling of buildings and other property is a common effect of high particulate levels.

The national primary standards for particulates are 75 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) for an annual geometric mean and $260 \mu\text{g}/\text{m}^3$ for a 24-hour average. Particles larger than 10 microns in diameter result from mechanical processes such as wind erosion, grinding and spraying, and the pulverizing of materials by vehicles and pedestrians. Particles between 1 and 10 microns in diameter usually include local soil, process dusts and combustion products from local industries, and (for maritime locations) sea salt. Combustion products and photochemical aerosols make up a large fraction of the particles in the range 0.1 to 1 micron in diameter and, although particles below 0.1 micron in diameter have not been extensively identified chemically, the typical urban increase over natural levels of particles in this size range seems to be entirely due to combustion.

There are significant natural sources of particulates, particularly in Alaska. Volcanic eruptions, blowing sand and dust, forest fires, and sea salt are all important. Vegetation also results in particulates. Some of these natural sources are summarized in Table II-II (Oliver, 1973). Man-made particulate emissions are becoming more and more important. In Alaska, the primary sources of man-made particulates are transportation, open burning, industrial and commercial sources, and power plants. The relative contributions of these sources are shown in Figure 2-2. The distribution of emissions by air quality region is given in Table II-III. There are two regions where the particulate standards have been exceeded — in Anchorage and Fairbanks. The problems in Anchorage are a function primarily of road dust and particulates generated by transportation. In Fairbanks, power plants and commercial and institutional sources are most important, but brush and forest fires in surrounding areas are also a major factor.

Particles suspended in the air scatter and absorb sunlight, reducing the amount of solar energy reaching the earth, producing hazes, and reducing visibility. Suspended particulate matter plays a significant role in bringing about precipitation, and



Source: TRW Systems Group, 1971

Figure 2-1. Air Quality Regions of Alaska

TABLE II-II. ESTIMATES OF PARTICLES SMALLER THAN 20-MICRON
RADIUS EMITTED INTO OR FORMED IN THE ATMOSPHERE*
(10⁶ metric tons per year)

Natural

Soil and rock debris**	100 — 500
Forest fires and slash-burning debris**	3 — 150
Sea salt (estimate)	(300)
Volcanic debris	25 — 150
Particles formed from gaseous emissions	
Sulfate from H ₂ S	130 — 200
Ammonium salts from NH ₃	80 — 270
Nitrate from NO _x	60 — 430
Hydrocarbons from plant exudations	<u>75 — 200</u>
Subtotal	<u>773 — 2200</u>

Man-Made

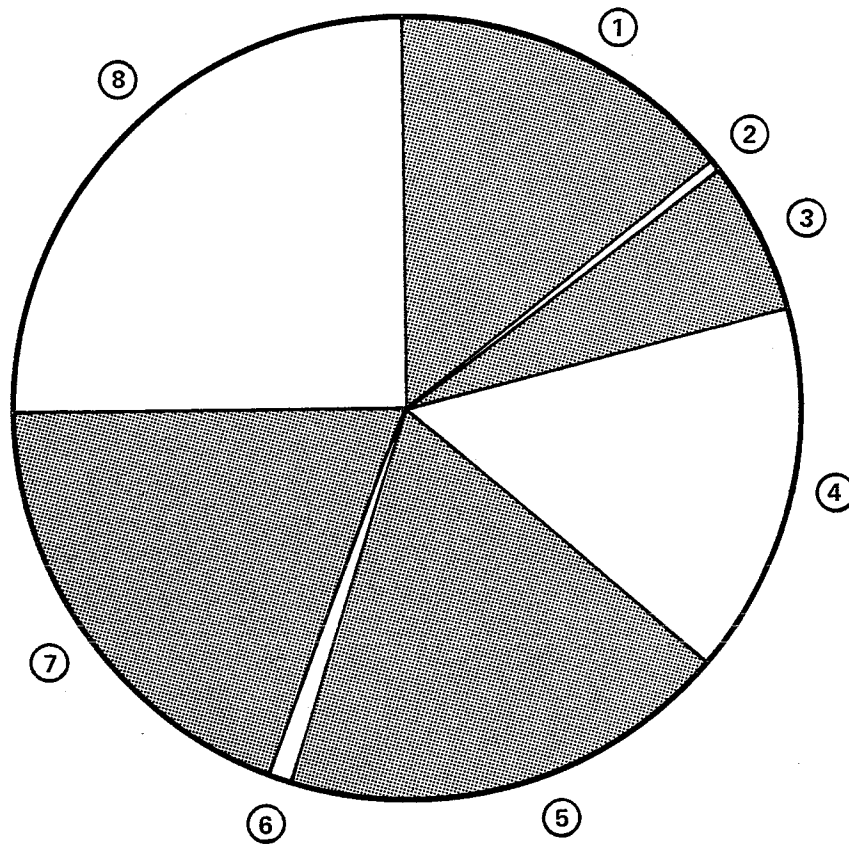
Particles (direct emissions)	10 — 90
Particles formed from gaseous emissions	
Sulfate from SO ₂	130 — 200
Nitrate NO _x	30 — 35
Hydrocarbons	<u>15 — 90</u>
Subtotal	<u>185 — 415</u>

Total

958 — 2615

* From SMIC (1971)

** Includes unknown amounts of indirect man-made contributions



①	POWER PLANTS	14.1%	⑤	INDUSTRIAL	18.6%
②	PROCESSES	0.4%	⑥	INCINERATION	0.8%
③	RESIDENTIAL	6.4%	⑦	OPEN BURNING	19.4%
④	COMMERCIAL AND INSTITUTIONAL	15.5%	⑧	TRANSPORTATION	24.8%

Source: TRW Systems Group, 1971

Figure 2-2. Annual Particulate Emissions by Source Category, Statewide, State of Alaska

TABLE II-III. SUMMARY OF TOTAL ANNUAL EMISSIONS

Air Quality Region	Particulates (tons/year)	Sulfur Oxides (tons/year)	Carbon Monoxide (tons/year)	Hydrocarbons (tons/year)	Nitrogen Oxides (tons/year)
Anchorage	2,626	3,017	108,044	29,637	22,085
Fairbanks	14,925	5,105	35,182	7,451	14,335
008	3,599	3,517	120,157	50,271	77,475
009	52,143	7,521	40,731	10,801	29,018
010	16,799	1,867	17,523	4,863	11,537
011	3,891	6,093	37,191	5,827	5,436
State Total	76,432	18,998	215,602	71,762	123,466

Note: Numbers in this table include emissions from forest fires.

Source: TRW Systems Group, 1971

there is some evidence that rainfall in cities has increased as the cities have developed industrially. For urban areas in the middle and high latitudes, particulate air pollution may reduce direct sunlight by as much as one third in the summer and as much as two thirds in the winter. This effect has implications for the delicate heat balance of the earth's atmospheric system.

Particles suspended in the air reduce visibility, or visual range, by scattering and absorbing light coming from both an object and its background, thereby reducing the contrast between them. On the average, visibility can be expected to be reduced to approximately 5 miles at a particulate concentration of $150 \mu\text{g}/\text{m}^3$. At a level of $100 \mu\text{g}/\text{m}^3$, visibility is reduced to 7-1/2 miles.

Particulate air pollution causes a wide range of damage to materials. Particulate matter may chemically attack materials through its own intrinsic corrosivity, or through the corrosivity of substances absorbed or adsorbed on it. Merely by soiling materials, and thereby causing their more frequent cleaning, particulates can accelerate deterioration.

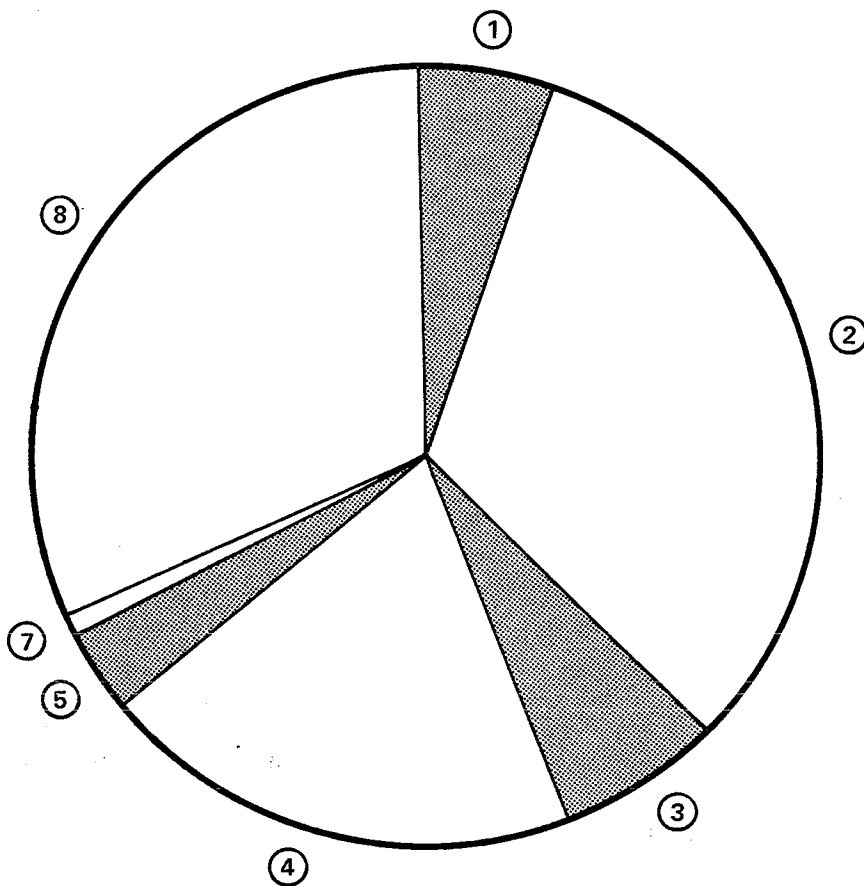
b. Sulfur Oxides

The presence of sulfur oxides in the ambient air has been associated with a variety of respiratory diseases and increased mortality rates. They represent a significant economic burden and have a nuisance impact. When sulfur oxides are inhaled with small particles, the health effect is increased. Inhalation of sulfur dioxide can cause increased airway resistance by constricting lung passages.

Sulfur dioxide may cause acute or chronic leaf injury to plants. Both acute and chronic injury may be accompanied by the suppression of growth and yield. Acute injury apparently affects the plant's ability to transform absorbed sulfur dioxide into sulfuric acid, and then into sulfates. At high rates of absorption, sulfite is thought to accumulate, resulting in the formation of sulfurous acid, which attacks the cells.

The sulfur oxides are common atmospheric pollutants which arise mainly from the combustion of fuels. Solid and liquid fossil fuels contain sulfur, usually in the form of inorganic sulfides or sulfur-containing organic compounds. The primary sources of sulfur oxides in Alaska are process units, transportation, and commercial and institutional combustion of fossil fuels. The relative contributions are shown in Figure 2-3. The amounts emitted in the different air quality regions of the state are shown in Table II-III. Ambient air quality standards for SO_2 have not been exceeded at any of the monitoring sites in Alaska.

Sulfur oxides are related to particulates in that the ultimate product of reactions of sulfur oxides is sulfates which are particulates. The reductions in visibility are



Source: TRW Systems Group, 1971

Figure 2-3. Annual Sulfur Oxide Emissions by Source Category, Statewide, State of Alaska

similar to those for particulates. Laboratory and field studies underscore the importance of the combination of particulate and sulfur oxide pollution in a wide range of damage to materials. Corrosion rates in steel are significantly higher when traces of sulfur dioxides are in the air. Sulfur oxide pollution attacks a wide variety of building materials — limestone, marble, roofing slate, and mortar — as well as statuary and other works of art, causing discoloration and deterioration. Sulfur oxide pollution contributes to the damage of electrical equipment of all kinds.

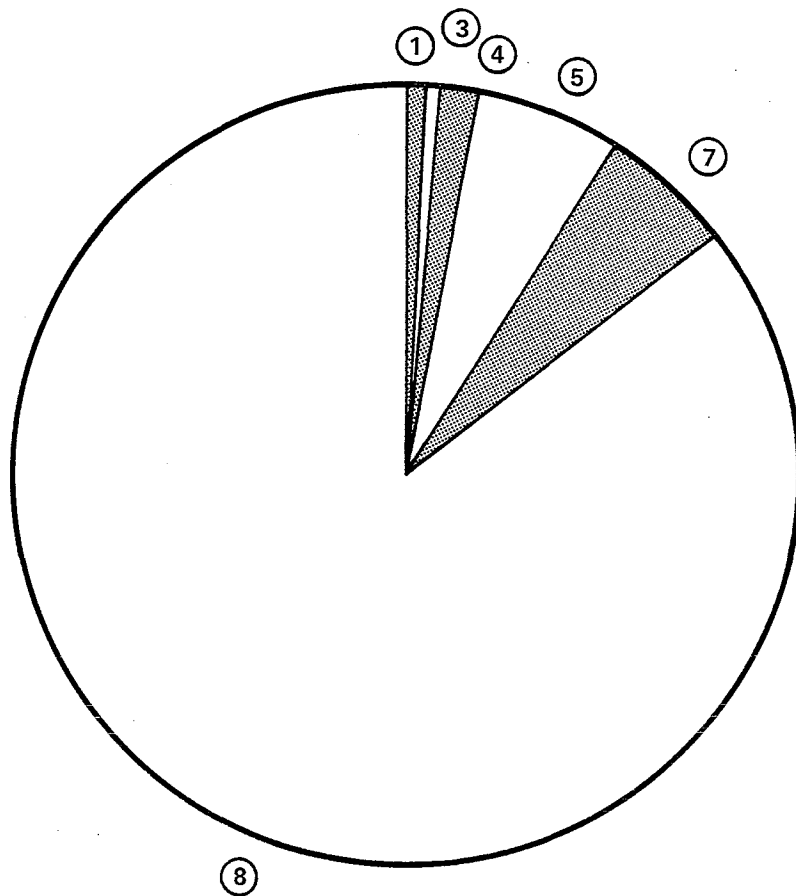
c. Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas arising primarily from the incomplete or inefficient combustion of carbonaceous fuels. CO is absorbed by the lung and reacts with the hemoglobin of the circulating blood. The absorption of CO is associated with a reduction in the oxygen-carrying capacity of blood and in the readiness with which the blood gives up its available oxygen to the tissues. The affinity of hemoglobin for CO is over 200 times that for oxygen.

The national primary standard for CO is based on evidence that levels of carboxyhemoglobin in human blood as low as 2.5 percent may be associated with impairment of the ability to discriminate time intervals. The national ambient air quality standards of 9 parts per million (ppm) for an 8-hour average and 35 ppm for a 1-hour average are intended to protect against the occurrence of carboxyhemoglobin levels above 2 percent. Evidence indicates that an exposure of 8 or more hours to a CO concentration of 30 ppm will produce blood carboxyhemoglobin levels of about 5 percent in nonsmokers and manifest impaired performance on other psychomotor tests.

Carbon monoxide is emitted to the atmosphere in greater quantities than any other urban air pollutant. The amounts of CO emitted by combustion depend on the efficiency of the burning process and so are a function of oxygen concentration, flame temperature, gas residence time, and combustion chamber turbulence. One limiting factor in the control of CO emissions comes from increasing the efficiency of the combustion by raising the temperature, but this results in increased nitrogen oxide emissions, which have been associated with a variety of respiratory diseases.

Figure 2-4 shows the analysis of carbon monoxide emissions by source type for the entire state of Alaska. It is clear that transportation sources predominate in emitting CO to the atmosphere. These emissions are concentrated in the vicinity of the cities of the state. In particular, Anchorage and Fairbanks both have days when the carbon monoxide standard is violated in the winter months. In Fairbanks, the monthly mean measured value is often above the 8-hour standard. The regional distribution of the carbon monoxide emissions is shown in Table II-III. Anchorage and Fairbanks contribute most of the emissions to their respective regions.



Source: TRW Systems Group, 1971

Figure 2-4. Annual Carbon Monoxide Emissions by Source Category, Statewide, State of Alaska

Both macrometeorological and micrometeorological factors play a role in the rate of dispersion of CO emissions. Micrometeorological factors, such as mechanical turbulence produced by automobiles and airflow around buildings, become important in determining street-side exposures. Macrometeorological factors can lead to air stagnation, which causes high community CO levels.

d. Other Pollutants

There are many other pollutants which are known to have health or nuisance effects. Some of these are summarized in Figure 2-5. Three pollutants have associated ambient air quality standards — photochemical oxidants, nitrogen oxides, and hydrocarbons. These are discussed briefly below.

(1) Photochemical Oxidants — Photochemical oxidants are produced in the atmosphere when nitrogen oxides and some hydrocarbons are exposed to sunlight. Photochemical oxidants cause irritation to the mucous membranes, damage to vegetation, and deterioration of materials. They affect the clearance mechanism of the lungs and alter resistance to respiratory bacterial infections. The national primary air quality standard for photochemical oxidants is based on evidence of increased frequency of asthma attacks for some people on days when hourly averages reach 0.1 ppm. Eye irritation is possible when atmospheric concentrations reach this level.

(2) Nitrogen Dioxide — Nitric oxide results from the fixation of nitrogen and oxygen at high temperatures as in fuel combustion. There are several atmospheric reactions which lead to the oxidation of nitric oxide to nitrogen dioxide, and the presence of nitrogen dioxide in ambient air is essential to the production of photochemical oxidants. The presence of nitrogen dioxide in ambient air has been associated with a variety of respiratory diseases. The statewide distribution of nitrogen oxide emissions is summarized in Figure 2-6 and Table II-III.

(3) Hydrocarbons — Defined as organic compounds composed exclusively of carbon and hydrogen, hydrocarbons are primarily associated with the use of petroleum products. They are the main components of photochemical smog. Hydrocarbons alone have no known effect on human health; therefore, the sole purpose of prescribing a hydrocarbon standard is to control photochemical oxidants. The statewide distribution of hydrocarbon emissions is summarized in Figure 2-7 and Table II-III.

3. Source Specific Emissions

The combustion of fossil fuels from each engineering action results in pollutants being emitted into the atmosphere. Many of the actions will result in pollution problems when associated with areas that already have problems or when the action itself is a

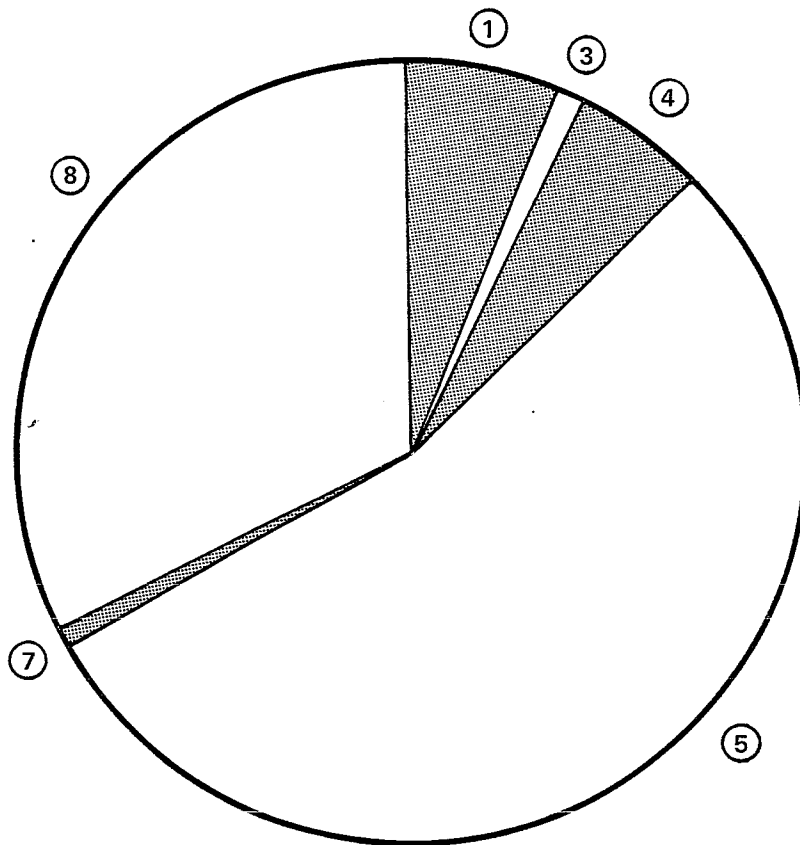
AIR POLLUTANTS	RECEPTORS					
	HEALTH	MATERIALS	SOILING	AESTHETICS	VEGETATION	ANIMAL
PARTICULATES						
SULPHUR OXIDES						
OXIDANTS						
CARBON MONOXIDE						
HYDROCARBONS						
NITROGEN OXIDES						
FLUORIDES						
LEAD						
POLYCYCLIC ORGANIC MATTER						
ODORS (INCLUDING HYDROGEN SULPHIDE)						
ASBESTOS						
BERYLLIUM						
HYDROGEN CHLORIDE						
CHLORINE						
ARSENIC						
CADMIUM						
VANADIUM						
NICKEL						
MANGANESE						
ZINC						
COPPER						
BARIUM						
BORON						
MERCURY						
SELENIUM						
CHROMIUM						
PESTICIDES						
RADIOACTIVE SUBSTANCES						
AEROALLERGENS						

Source: U.S. President's Council on Environmental Quality, 1971



DELETERIOUS EFFECTS

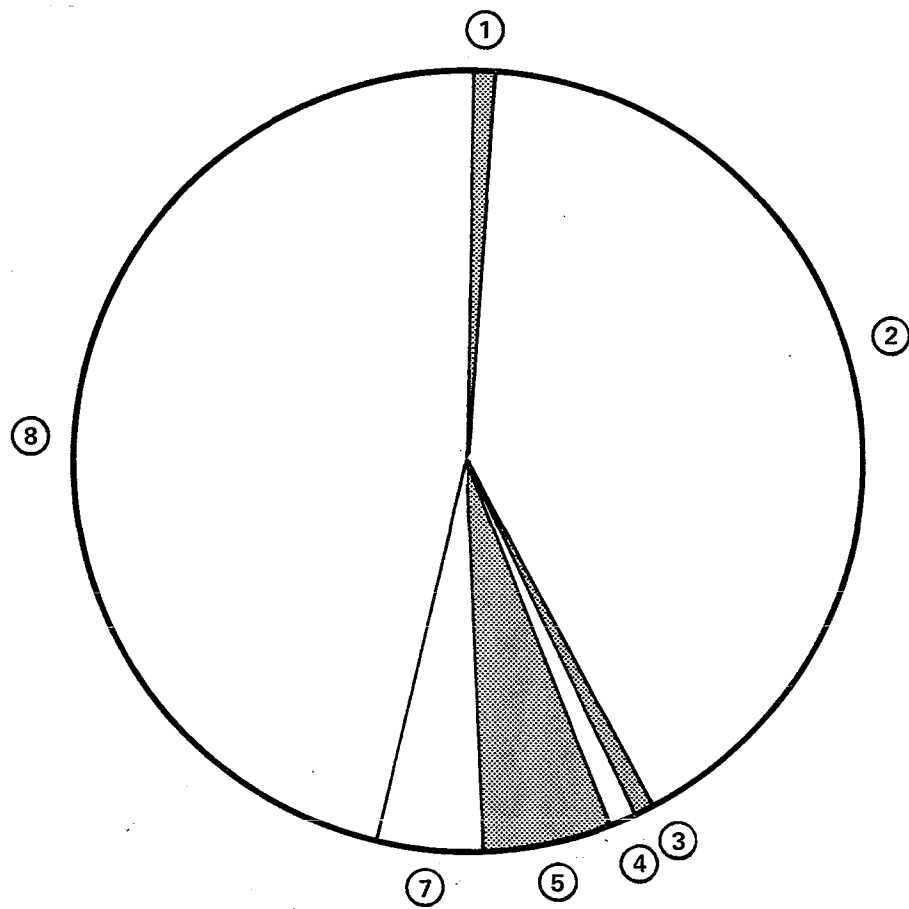
Figure 2-5. Effects of Air Pollutants Upon Various Receptors in the United States



①	POWER PLANTS	6.4%	⑤	INDUSTRIAL	54.3%
②	PROCESSES	0.0%	⑥	INCINERATION	0.0%
③	RESIDENTIAL	1.0%	⑦	OPEN BURNING	0.6%
④	COMMERCIAL AND INSTITUTIONAL	5.6%	⑧	TRANSPORTATION	32.1%

Source: TRW Systems Group, 1971

Figure 2-6. Annual Nitrogen Oxide Emissions by Source Category, Statewide, State of Alaska



Source: TRW Systems Group, 1971

Figure 2-7. Annual Hydrocarbon Emissions by Source Category, Statewide, State of Alaska

large-scale effort. The estimated pollution amounts are described in the discussion for each action.

Some of the equipment that is associated with certain engineering actions will come under new source performance standards and will be required to use the latest control technology to keep the emissions of carbon monoxide, particulates, sulfur dioxides, nitrogen oxides, and hydrocarbons to a minimum. The placement of some major pollution sources with high particulate and sulfur oxide emissions will be governed in part by nondegradation limits imposed by federal regulations, depending on how the State classifies different areas of the state. For purposes of the estimation of impacts by physiographic unit, these general impacts are combined with an estimate of the extent of projects and existing problems in each region.

4. Addition of Water Vapor to the Atmosphere

Most of the engineering actions involve the release of water vapor to the atmosphere, which may modify the humidity, cloudiness, or precipitation locally or regionally, depending on the scope of the project. In the summer months, when the air is warmer and can hold more water vapor, these effects will be small, if detectable at all. In the winter, however, when the air is cold and can hold little water vapor, the incidence of fogs, clouds, riming, and changes in precipitation patterns may be important.

Ice fog is the visible aspect of a man-made air pollution problem which becomes a nuisance whenever temperatures go below -35 degrees C, particularly in the Fairbanks/Fort Wainwright area of interior Alaska. It is produced by water vapor output from automobile exhaust, power plant stacks, household chimneys, and other sources associated with urban environments. Aside from areas with sources of water vapor, such as hot springs and caribou herds, ice fog is restricted to populated areas. Its thickness is generally about 10 meters and rarely exceeds 30 meters, but its thickness and density increase as temperature decreases, especially below -40 degrees C. The reduction of visibility by ice fog, although serious in itself, is only one of the more obvious manifestations (Benson, 1970). Ice fog is also seen to hang in the air for long periods of time after the passage of aircraft and motor vehicles and may significantly reduce the visibility on roads and runways.

Power plants require cool water to condense the steam produced in generating power. Estimates of water and carbon dioxide produced by the combustion of gasoline, fuel oil, and coal (from Benson, 1970) are shown in Table II-IV. Table II-V gives an estimate of the relative contributions of different sources to the problem. Automobiles represent a larger problem than the percentages indicate because of their concentration downtown (with the additional miscellaneous sources there) and because of the critical reduction in visibility, particularly at intersections, due to idling at traffic signals.

TABLE II-IV. WATER AND CARBON DIOXIDE PRODUCED BY THE COMBUSTION OF GASOLINE, FUEL OIL, AND COAL IN AIR IN THE FAIRBANKS/FORT WAINWRIGHT AREA DURING COLD SPELLS

Source	kg + Combustion in Air	=	kg H ₂ O	+	kg CO ₂
Gasoline					
Monthly	2,700,000		3,720,000		8,400,000
Daily	90,000		124,000		279,000
Fuel Oil					
Monthly	4,600,000		6,100,000		14,400,000
Daily	152,000		202,000		475,000
Coal, Domestic					
Monthly	9,100,000		6,190,000		21,500,000
Daily	305,000		207,000		720,000
Coal, Power Plants					
Monthly	33,600,000		23,850,000		79,400,000
Daily	1,118,000		760,000		2,640,000
Total Combustion Products					
Monthly			39.9 x 10 ⁶		123.7 x 10 ⁶
Daily			1.3 x 10 ⁶		4.1 x 10 ⁶

Source: Benson, 1970

TABLE II-V. SUMMARY OF MAN-MADE WATER SOURCES
FOR THE FAIRBANKS ATMOSPHERE

Source	Amount ($\times 10^6$ g H ₂ O day ⁻¹)	Percent
Combustion Products		
Gasoline	124	3
Fuel oil	202	5
Coal, domestic	207	5
Coal, power plants	760	19
Cooling water from power plants	2600	64
Miscellaneous (leaks from steam lines, houses, university mine shaft, sewage, people and animals breathing, etc.)	170	4
Total	4063	100

Source: Benson, 1970

Besides this very visible effect of the addition of water vapor to the atmosphere, there are less obvious increases in water vapor from the same sources. When the number of sources increases in a small area, as in some of the more complex engineering actions, the effects may begin to become perceptible and the local climate may exhibit some modifications.

5. Modifications of Temperatures and Winds

Heat island effects have been noted in several cities, including Fairbanks. The temperature in the city exceeds that of the surrounding flats by 5 to 6 degrees when the air temperature is in the -40 to -45 degrees C range, and by about 3 degrees in the -20 degrees C range (Benson, 1970). The waste heat that is cast off during the processes of energy generation and consumption is as much a climatic contaminant as are the gases and particles that are put into the atmosphere. It is known that a concentration of heat sources (for example, a city) affects local climate (Peterson, 1969). The hard question is at what point will waste heat become a climatic factor. The ability to answer this question is hampered by

the necessarily crude estimates of future power generation amounts and locations and by the still-uncertain understanding of the dynamic process by which this heat would affect global climate (*Study of Critical Environmental Problems*, 1970).

Cities also affect the winds of an area. Because of the building and other structures associated with towns and cities, the surface roughness is increased and the speeds of winds in the city are reduced. However, greater turbulence is generated. While the average wind speed is decreased, local effects, such as the channeling of winds through "city canyons," often give the opposite impression. When regional winds are light, a city creates its own windfield. The wind responds to the heat island effect and also the surface anomalies occurring in the city (Oliver, 1973).

6. Changes in the Heat Balance that Affect Microclimatology

Many of the engineering actions discussed may change the albedo of the surface and/or the thermal characteristics of the soil. These are two important facets of the heat balance near the surface as described more fully in *The Environment of Alaska: Analysis of Physical and Biological Determinants* (John Graham Company, 1976), Section II.A. Changes in cloudiness and in particulate loading in the atmosphere are discussed above and also affect the radiation balance.

Surface properties of the ground surface (or snow surface, depending on season) determine how much radiation is absorbed or reflected. This is related to the albedo or reflectivity of the surface and can be modified by dust on snow surfaces or changes in surface cover (e.g., clearing land, paving of surface, reservoirs). The thermal conductivity of the surface controls the distribution of absorbed heat between the ground and the air. Removal of surface layers in clearing and replacement with paving, gravel, fill, or tailing will alter the thermal structure of the soil.

Changes in cloud cover affect the amount of incoming solar radiation and the amount of terrestrial radiation reflected back to earth. Particulate matter in the atmosphere will also affect the amounts of incoming solar radiation.

B. NOISE

1. Background

a. General

Three dimensions of environmental noise are important in determining man's subjective response. These are (1) the intensity or level of the sound, (2) the frequency

spectrum of the sound, and (3) the time-varying character of the sound. Airborne sound is caused by rapid fluctuation of air pressure above and below atmospheric pressure. Sound levels are usually measured and expressed in decibels (dB), with 0 dB corresponding roughly to the threshold of sensitivity or hearing.

The frequency of a sound refers to the number of complete pressure fluctuations per second in the sound. The unit of measurement is cycles per second (cps) or, more commonly, hertz (Hz). Most environmental sound consists of a broad band of frequencies which differ in relative level. The quantitative expression of the frequency and level content of a sound is its sound spectrum. Many rating methods have been devised to permit comparison of sound having quite different spectra. Fortunately, the simplest method correlates with human response practically as well as the more complex methods (Parkin, 1964; Galloway, et al, 1969; Botsford, 1969). This method consists of evaluating all of the content of a sound in accordance with a weighting that progressively and severely deemphasizes the importance of frequencies below 1000 Hz, with mild deemphasis above 5000 Hz. This type of frequency weighting reflects the fact that human hearing is less sensitive at low frequencies and extreme high frequencies than it is in the frequency midrange. The weighting curve most often used is called *A-weighting*, and the level so measured is called the *A-weighted sound level*, or simply *A-level*.

The A-level in dB is expressed as dBA; the letter A is a notation of the weighting used to obtain the measurement. In practice, the A-level of a sound source is conveniently measured using a sound level meter with an electrical filter corresponding to the A-weighting curve. All American and international standard sound level meters include such a filter.

Although the A-level may adequately describe environmental noise at any instant in time, the fact is that the community noise level varies continuously. Most environmental noise includes a multiplicity of distant noise sources which create a relatively steady background noise in which no particular source is identifiable. These distant sources may include traffic, wind in trees, industrial or farming activities, etc. Those noise sources are relatively constant from moment to moment, but vary slowly from hour to hour as natural forces change or as human activity follows a daily cycle. Superimposed on this slowly varying background is a succession of identifiable noisy events of brief duration. These may include nearby activities or single vehicle passages, aircraft flyovers, etc., which cause the environmental noise level to vary from instant to instant.

Following standard practice, this report has accounted for the varying character of environmental sound through statistics (Kittleson and Paulsen, 1964; Scholes and Vulcan, 1969; Scholes, 1971). The statistical descriptor used in this report is the A-level that is exceeded 10 percent of the time, designated by the symbol L_{10} . L_{10} is considered a good measure of the "average peak" noise. Close to a highway, where noise levels vary from

moment to moment, human response probably relates more to the noise peaks, such as from individual vehicle passages, rather than to the median sound level, L_{50} , the A-level which is exceeded 50 percent of the time.

The L_{50} level is easier to calculate than L_{10} , but its use as a predictor of human response to traffic noise is most appropriate at a distance from a heavily traveled roadway. At the other end of the statistical scale is L_{90} , the A-level exceeded 90 percent of the time. This is considered a good measure of background noise at a site.

b. Construction Noise

Construction noise sources, despite the variety and types of equipment used, have similarities which permit their grouping into a limited number of categories. These categories are described below and shown graphically in Figure 2-8, together with the corresponding noise levels associated with their use. The most prevalent noise source in construction equipment is from the prime mover (i.e., the internal combustion engine, usually diesel) used to provide motive or operating power. Within these categories, engine noise predominates with exhaust noise being most significant and inlet and structural noise being secondary. Engine-powered equipment may be categorized according to its mobility and operating characteristics — earth-moving equipment, highly mobile; handling equipment, partly mobile; and stationary equipment.

Construction proceeds in several systematic, discrete phases, each having a characteristic mix of equipment and consequent noise. Building construction of the type planned is characterized by five major phases (Bolt, Beranek, and Newman, 1971a).

- I Clearing, demolition, and site preparation
- II Excavation
- III Placing foundations
- IV Frame erection, floors and roof, skin and windows
- V Finishing, cleanup

Defining these construction phases makes it possible to account for variations in site noise output with time.

The model used in construction noise projections was determined on the basis of information obtained on the following factors (Bolt, Beranek, and Newman, 1971a):

- The number of each item of equipment typically present at a site (in a given phase)

NOISE LEVEL (dBA) AT 50 FT.*			60	70	80	90	100	110
EQUIPMENT POWERED BY INTERNAL COMBUSTION ENGINE	EARTH MOVING	COMPACTORS (ROLLERS) FRONT LOADERS BACKHOES TRACTORS SCRAPERS, GRADERS PAVERS TRUCKS						
	MATERIALS HANDLING	CONCRETE MIXERS CONCRETE PUMPS CRANES (MOVEABLE) CRANES (DERRICK)						
	STATIONARY	PUMPS GENERATORS COMPRESSORS						
	IMPACT EQUIPMENT	PNEUMATIC WRENCHES JACKHAMMERS, ROCK DRILLS PILE DRIVERS (PEAKS)						
	OTHER	VIBRATORS SAWS						

SOURCE: EPA (NTID 300.1, 1971)
*BASED ON LIMITED DATA SAMPLES

Figure 2-8. Construction Equipment Noise Ranges

- The length of the duty cycles of this equipment
- The average noise levels during operation
- The noisiest piece of equipment located 50 feet from an observer
- All other equipment located 200 feet from the observer
- With ambient levels surrounding the site taken to be present in addition to the equipment noise

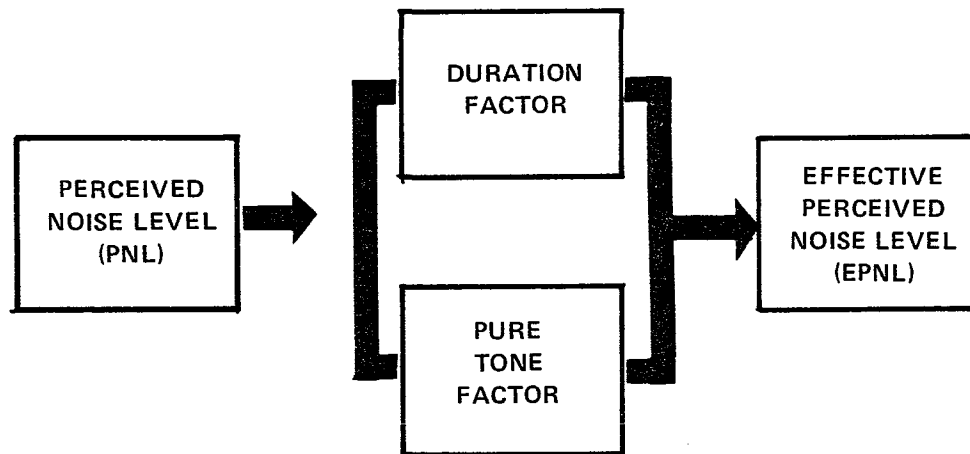
c. Traffic Noise

There are many factors influencing roadway noise levels, including the nature of the road surface, speed of travel, road gradient, road configuration, vertical configuration, the presence of barriers or other shielding, observer distance, and vehicle mix. Traffic noise has two major constituents — engine/exhaust and tire/roadway interaction. A significant number of cars built by major manufacturers produce equal amounts of engine/exhaust and tire/roadway interaction noise under normal operation. During acceleration, the engine/exhaust component is predominant. However, trucks are considerably noisier than automobiles, due to increased tire/roadway interaction. Under similar conditions, a truck can produce from 10 to 15 dBA more than a car. The greater the percent of trucks on a given roadway, the higher will be the L_{10} level or peak noise levels. Increases in the L_{10} are generally associated with increased annoyance (Gordon, et al, 1971).

d. Aircraft Noise

Three noise environment descriptions are currently in use in the United States for describing aircraft noise — NEF, CNEL, and CNR. The Noise Exposure Forecast (NEF) and Community Noise Equivalent Level (CNEL) are obtained from the Effective Perceived Noise Level (EPNL) and Single Event Noise Exposure Level (SENEL), respectively, by applying correction factors for the number of aircraft events occurring within certain specified time periods during a 24-hour day. Weighting factors are applied for operations in various periods to account for the increased sensitivity to noise in the evening and nighttime hours. Corrections for time of day and number of operations are also included in the calculation of the Composite Noise Rating (CNR), which is the predecessor of the NEF. However, the CNR is based on the maximum Perceived Noise Level (PNL), with no integration or correction for the duration of the aircraft noise signal, and no tone correction. Figure 2-9 shows the derivation of the noise event and the noise environment descriptors used in this report. Figure 2-10 shows the relation of NEF to familiar sounds and typical aircraft noise environments.

NOISE EVENT DESCRIPTOR



NOISE ENVIRONMENT DESCRIPTOR

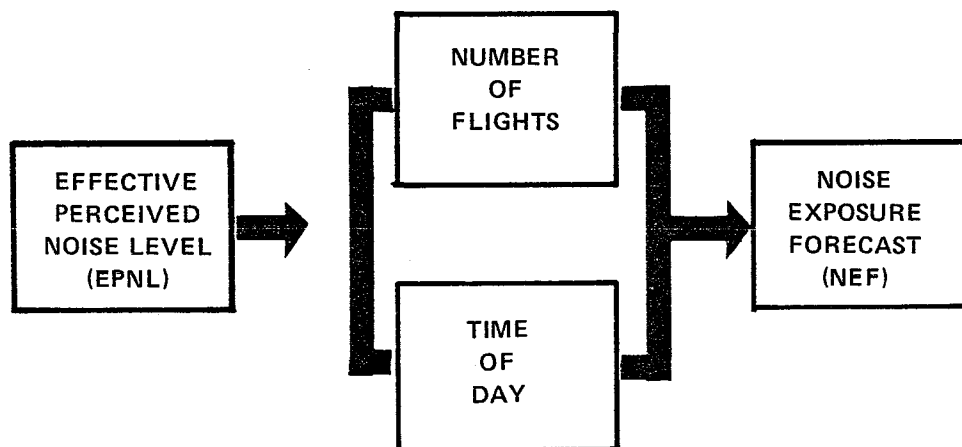


Figure 2-9. Derivation of Noise Event and Noise Environment Descriptors

TRANSPORTATION NOISES

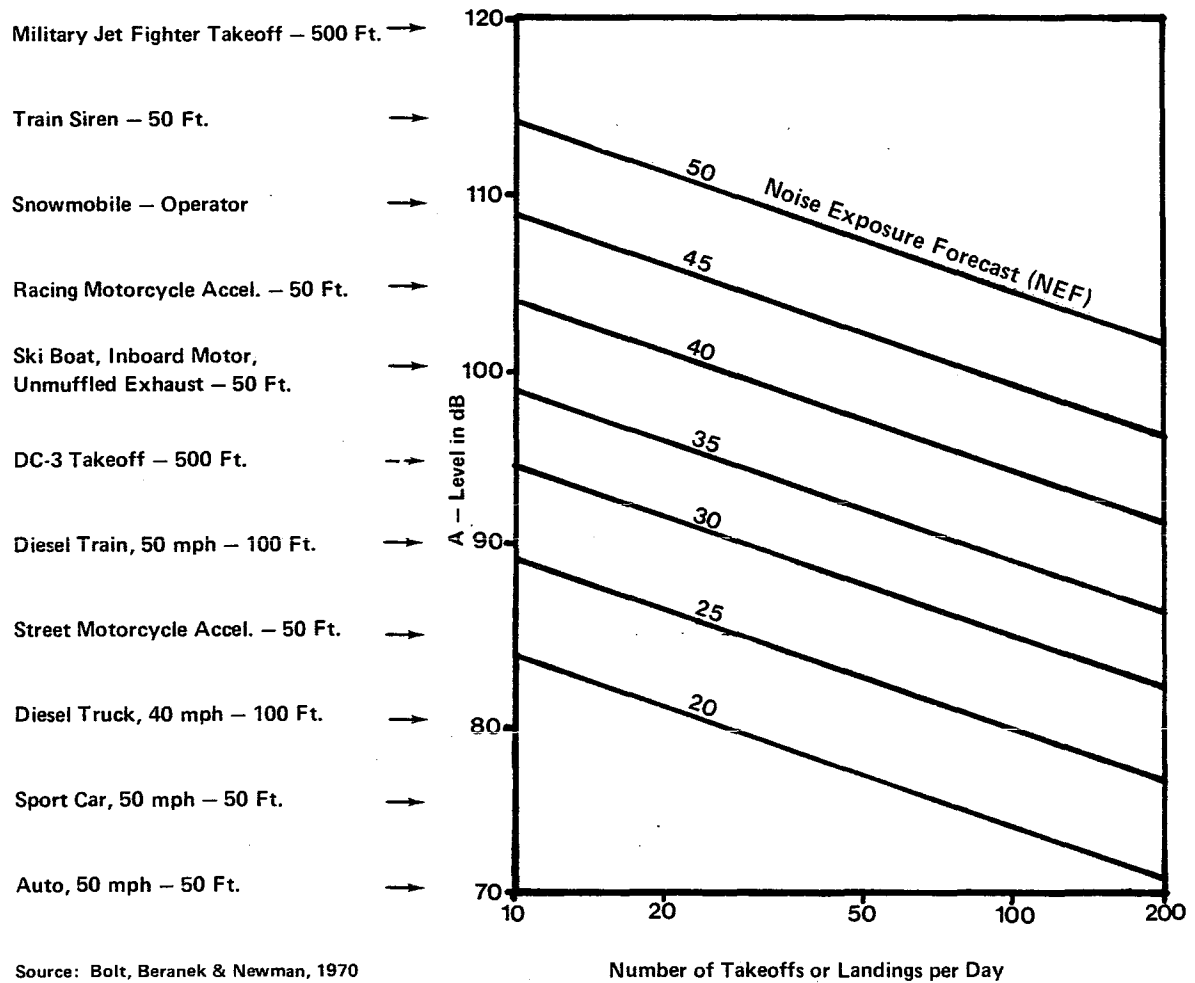


Figure 2-10. NEF Values and Common Transportation Noises

The primary type of aircraft used in Alaska currently is the non-jet-propeller-driven, single- or twin-engine aircraft. The noise generated by these aircraft can be separated into vortex and rotational components. Vortex noise is the major source of broadband noise and is generated by the formation and shedding of vortices (whirlpools of air) in the flow past the blade. The major source of rotational noise is due to oscillations of the pressure field on the air due to the passage of the blade. This rotational noise creates discrete frequency noises at harmonics of the blade passage frequency.

2. Noise Projections

a. Highway Noise Model

Noise level projections were made for the traffic activity using a model presented in the National Cooperative Highway Research Program Report 117, *Highway Noise – A Design Guide for Highway Engineers* (Gordon, et al, 1971). This model employs three basic parameters for noise level prediction:

- Roadway characteristics
- Observer characteristics
- Traffic characteristics

Based on the traffic characteristics of peak volumes, percent truck mix, and maintainable speeds, the program yields a reference L_{50} noise level at a specified distance of 100 feet from the near lane of traffic. Subsequent adjustments to the reference level are made for the unique roadway and observer characteristics. The adjusted values yield the predicted L_{50} and L_{10} levels for a specific location. The following adjustments are characteristic of the highway noise model:

- Distance: -4 to -5 dBA for doubling
- Volume: +3 dBA for doubling
- Speed: +9 dBA for doubling
- Ground Cover: -0 to -3 dBA per 100 feet
- Gradient: +3 dBA for 5 percent grade (trucks only)
- Barriers: -5 to -15 dBA, depending on height, thickness, slope, and material used

b. Construction Noise Model

Noise level projections were made for the construction activity using a model presented in *Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances* (Bolt, Beranek, and Newman, 1971a). The model is based on the average levels produced by construction equipment. A list of present average levels for various types of equipment is shown in Table II-VI. The projected levels based on this construction noise model also take into account the reduction of noise levels based on divergence decrease due to spreading of the sound waves and the transmission loss experienced for noise levels within a building or home with closed windows (Harris, 1957).

c. Aircraft Noise Model

Because of the similarity of the various aircraft currently in use in Alaska, it may be convenient to group them into a single class characterized by an EPNL vs distance curve and a set of takeoff and landing profiles. The takeoff and landing profiles are then combined with the EPNL vs distance curves to give a set of EPNL contours. A single EPNL contour will depict on a map of the area about an airport the EPNL due to one particular operation of a certain class of aircraft.

The total noise exposure produced by aircraft operations at a given point is viewed as being composed of the EPNL's produced by each aircraft class on different flight paths. For a given aircraft class on a given flight path, the NEF can be expressed as

$$NEF = EPNL + 10 \log (N_D + N_E + 16.67 N_N) - 88$$

where

$$\begin{aligned} N_D &= \text{Number of flights during the day (0700/1900)} \\ N_E &= \text{Number of flights during evening (1900/2200)} \\ N_N &= \text{Number of flights during the night (2200/0700)} \end{aligned}$$

3. Impact Evaluation

a. Environmental Protection Agency, Suggested Noise Impact Criteria

The Environmental Protection Agency criteria (Wyle Laboratories, 1971) are based on the amount of increase attributable to a new noise source. Increases are divided into three ranges as they relate to expected community response:

- Up to 5 dBA Increase — Few complaints if increase is gradual

TABLE II-VI. PRESENT AVERAGE NOISE LEVELS
IN dBA FOR CONSTRUCTION EQUIPMENT

<u>Equipment</u>	<u>Noise Level in dBA at 50 Feet</u>
Earth-moving equipment	
Front loader	79
Backhoes	85
Dozers	80
Scrapers	88
Tractors	80
Graders	85
Truck	91
Paver	89
Material handling equipment	
Concrete mixer	85
Concrete pump	82
Crane	83
Derrick	88
Stationary equipment	
Pumps	76
Generators	78
Compressors	81
Impact equipment	
Pile drivers	101
Jackhammers	88
Rock drills	98
Pneumatic tools	86
Other equipment	
Saws	78
Vibrators	76

Source: Bolt, Beranek, and Newman, 1971a

- 5 to 10 dBA Increase — More complaints, especially if conflict with sleeping hours
- Over 10 dBA Increase — Substantial number of complaints

Relative to these ranges, generally no attention is needed if the increase is less than 5 dBA. Some consideration should be given to additional abatement measures if the range increase is 5 to 10 dBA. If the increase is over 10 dBA, the impact is considered serious and warrants close attention.

b. Department of Housing and Urban Development, Noise Assessment Guidelines

These guidelines (Bolt, Beranek, and Newman, 1971b) are primarily used to determine if new construction sites are compatible with residential development. However, the reverse can also be applied to determine if the noise levels produced by construction sites are compatible with present residential uses. The noise levels are based on time-weighted permissible exposures as shown in Table II-VII.

c. National Cooperative Highway Research Program, Report 117

This report (Gordon, et al, 1971) suggests recommended design criteria for various building types, as shown in Table II-VIII. These criteria have been derived from previous research projects and specify maximum noise levels that would be considered acceptable by the average individual with respect to sleep interference, speech, radio and television interference, and annoyance. Noise impact is determined for each building type by comparing existing and future noise levels. As shown in Figure 2-11, when the existing level is above the criteria, an increase of 1 to 5 dBA results in *some impact*. An increase of 6 dBA or more would result in *great impact*. If the existing level is below the criteria, an increase of 0 to 5 dBA would cause *no impact*, 6 to 15 dBA would cause *some impact*, and more than 15 dBA increase would be considered *great impact*. This method can be applied to the inside/outside recommended design criteria. Table II-IX shows the inside/outside noise reduction that can be expected for various types of structures by geographical area.

d. Speech and Sleep Interference

Background noise above certain levels interferes with one's ability to understand oral communication and disturbs sleep. Figure 2-12 illustrates some current knowledge regarding speech interference.

TABLE II-VII. NOISE ASSESSMENT GUIDELINES,
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

General External Exposures (dBA)

Unacceptable

Exceeds 80 dBA 60 minutes per 24 hours

Exceeds 75 dBA 8 hours per 24 hours

Normally Unacceptable

Exceeds 65 dBA 8 hours per 24 hours

Loud repetitive sounds on site

Normally Acceptable

Does not exceed 65 dBA more than 8 hours per 24 hours

Acceptable

Does not exceed 45 dBA more than 30 minutes per 24 hours

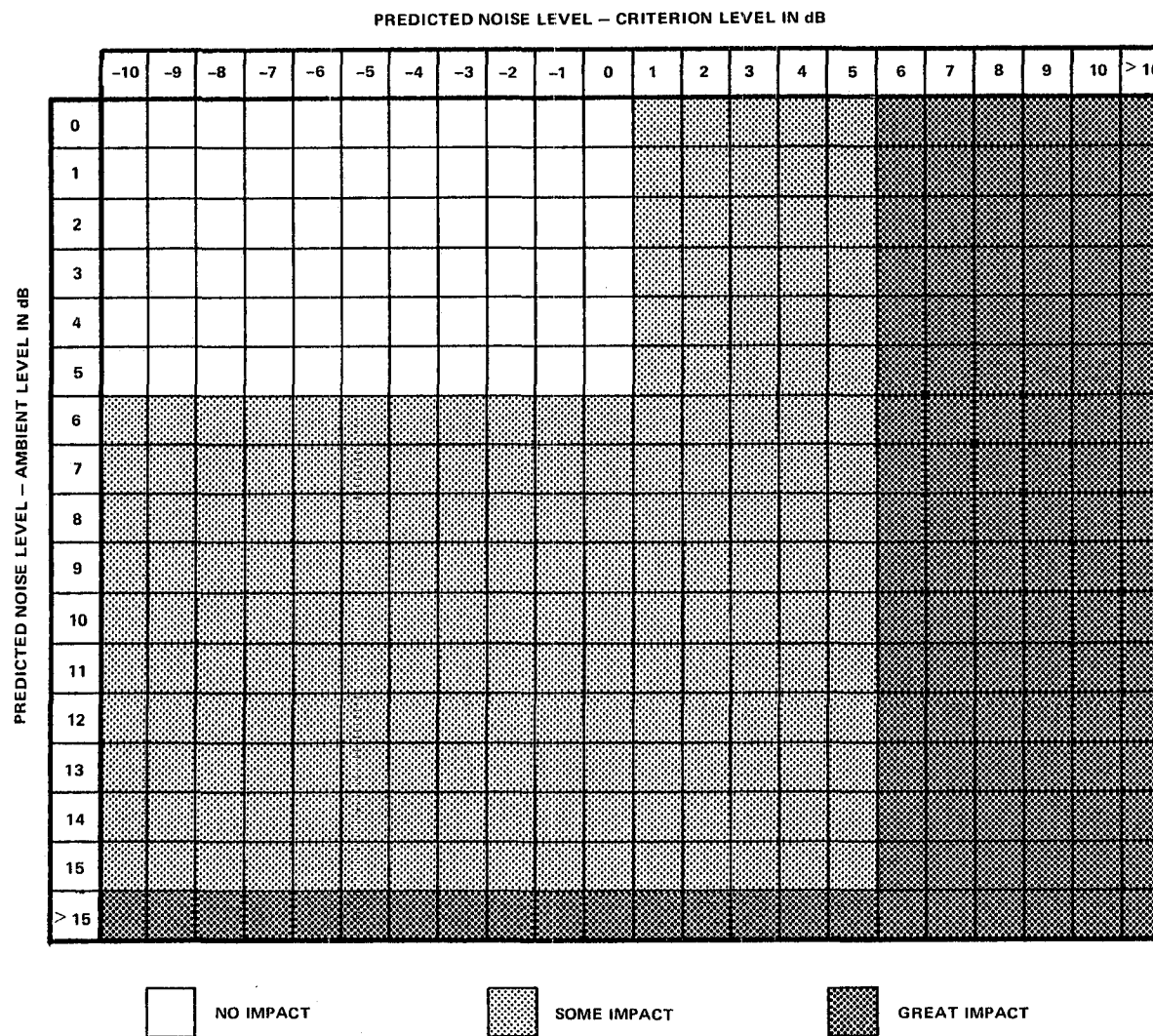
Source: Bolt, Beranek, and Newman, 1971b

TABLE II-VIII. RECOMMENDED DESIGN CRITERIA

Structure		L ₅₀ (dBA)		L ₁₀ (dBA)	
		Day	Night	Day	Night
Residences	Inside*	45	40	51	46
Residences	Outside*	50	45	56	51
Schools	Inside*	40	40	46	46
Schools	Outside*	55	----	61	----
Churches	Inside	35	35	41	41
Hospitals	Inside	40	35	46	41
Convalescent Homes	Outside	50	45	56	51
Offices					
Stenographic	Inside	50	50	56	56
Private	Inside	40	40	46	46
Theaters					
Movie	Inside	40	40	46	46
Legitimate	Inside	30	30	36	36
Hotels and Motels	Inside	50	45	56	51

* Either inside or outside design criteria can be used, depending on the utility being evaluated.

Source: Gordon, et al, 1971



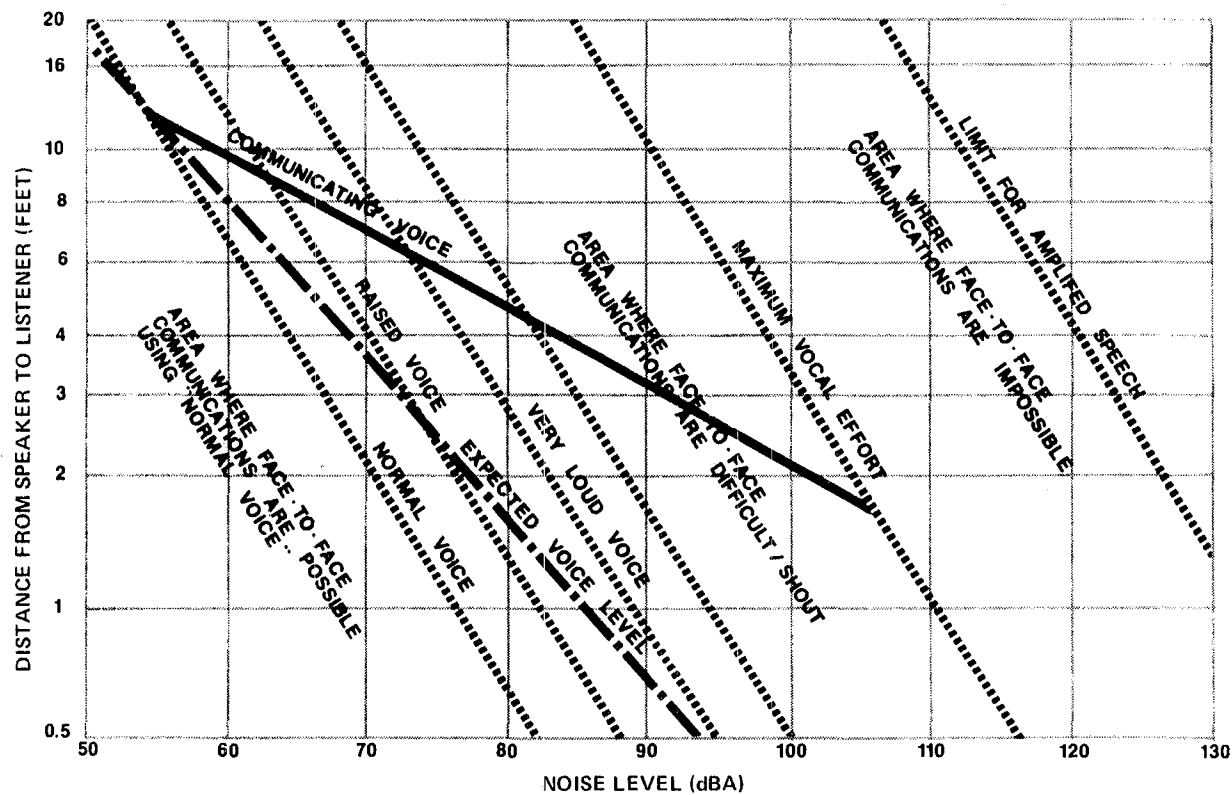
Source: Gordon, et al, 1971

Figure 2-11. Impact Evaluation When Predicted Noise Levels Exceed Criteria

TABLE II-IX. OUTSIDE/INSIDE NOISE REDUCTION

Structure	Geographic Area	Open Windows (dBA)	Closed Windows (dBA)
Residences	South and southwest	12	20
	North and northeast	17	25
Schools	South and southwest	12	20
	North and northeast	17	25
Churches	All areas	20	30
Hospitals Convalescent Homes	All areas	17	25
Offices	All areas	17	25
Theaters	All areas	20	30
Motels and Hotels	South and southwest	12	20
	North and northeast	17	25

Source: Gordon, et al, 1971



VOICE LEVEL AND DISTANCE BETWEEN TALKER AND
LISTENER FOR SATISFACTORY FACE-TO-FACE SPEECH
COMMUNICATIONS AS LIMITED BY AMBIENT NOISE

SOURCE: "SIL - PAST, PRESENT, AND FUTURE",
J.C. WEBSTER, SOUND AND VIBRATION,
AUGUST, 1969

Figure 2-12. Speech Interference Levels

- e. U.S. Department of Transportation, Federal Highway Administration, *Policy and Procedure Memorandum* (PPM 90-2), 1973

This document requires (1) identification of existing developed land uses which may be affected by highway noise; (2) prediction of highway-generated noise levels from anticipated future traffic on the facility; (3) measurement of existing noise levels; and (4) comparison of predicted levels with both existing levels and design noise levels listed in the noise standards. The design noise level standards are based on the L_{10} level. The design noise level/land use relationships are shown in Table II-X. Where projected noise levels exceed the design noise levels for a particular land use activity, identification and analysis of feasible noise abatement measures are required.

- f. Impact Estimate for NEF Values, Department of Housing and Urban Development

This document (Wilsey and Ham, 1972) compares the impact estimate for various NEF values to numerous human activities, as shown in Table II-XI. Four categories of impact are used:

- Low Impact — Activity can be performed with little or no interruption from aircraft noise, though noise may be noticeable above background levels.
- Moderate Impact — Activity can be performed, but with some interference from aircraft noise due to level or frequency of interruptions.
- Serious Impact — Activity can be performed, but only with difficulty due to level or frequency of aircraft noise.
- Critical Impact — Activity cannot be performed acceptably in the aircraft noise environment.

The effects of noise and vibration on wildlife are described in Section II.D.6 and in the analyses of specific actions in Section IV of the report.

C. WATER QUALITY

This section describes and discusses the major parameters which can affect the quality of water including turbidity, toxic or deleterious substances, dissolved oxygen content, acidity and alkalinity, temperature, nutrients, coliforms, and water movement. The

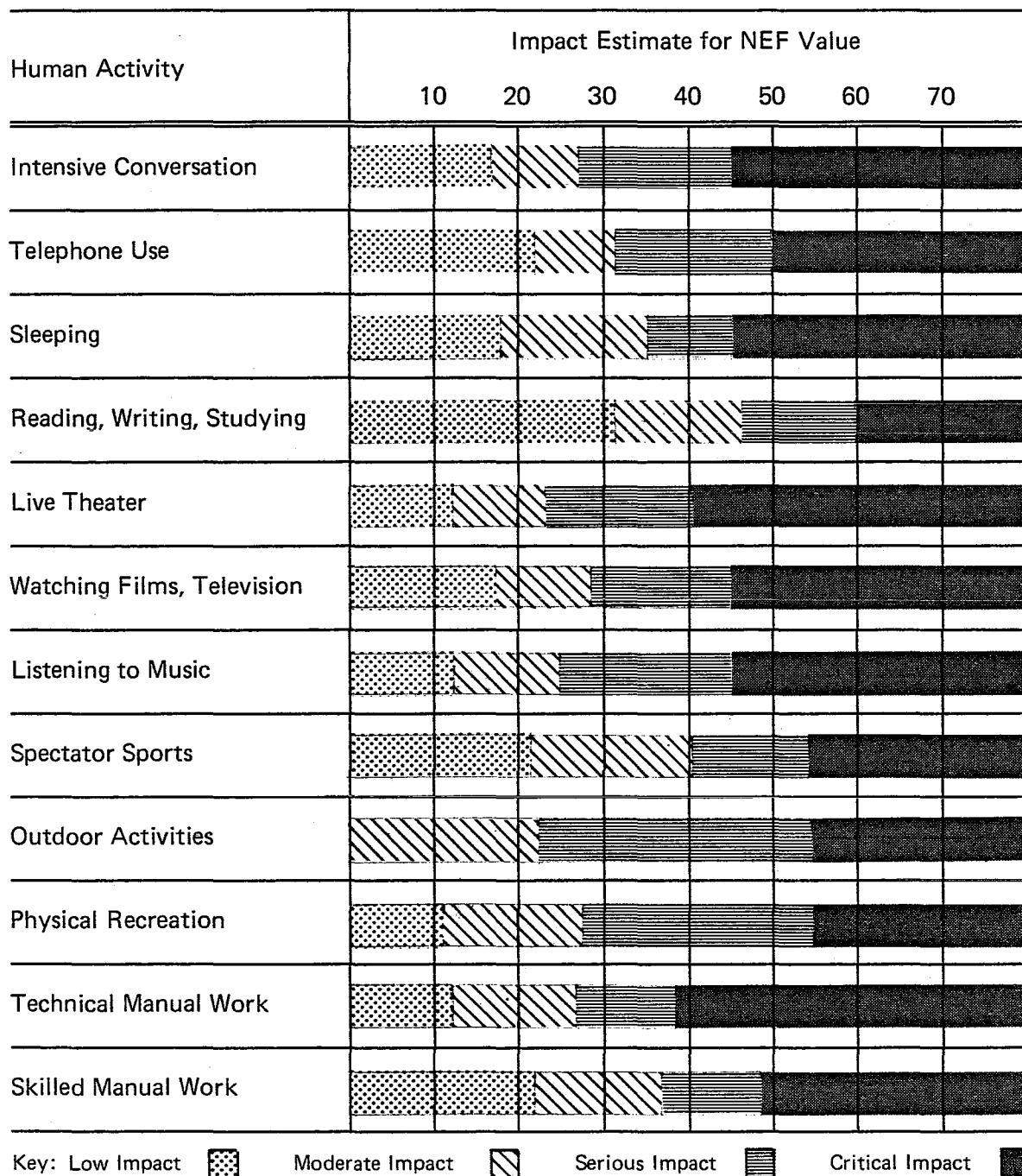
TABLE II-X. DESIGN NOISE LEVEL/LAND USE RELATIONSHIP

Land Use Category	Design Noise Level — L_{10}	Description of Land Use Category
A	60 dBA (exterior)	Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particular parks or portions of parks, or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
B	70 dBA (exterior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, picnic areas, recreational areas, playgrounds, active sports areas, and parks.
C	75 dBA (exterior)	Developed lands, properties, or activities not included in Categories A and B, above.
D	---	For requirements on undeveloped lands, see paragraphs 5a(5) and (6) of PPM 90-2.
E*	55 dBA (interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

* The interior design noise level in Category E applies to indoor activities for those situations where no exterior sensitive land use or activity is identified.

Source: U.S. Department of Transportation, 1973

TABLE II-XI. AIRCRAFT NOISE IMPACT ON SOME
HUMAN ACTIVITIES, BASED ON NEF VALUE



Source: Wilsey and Ham, 1972

subsequent effects of a change in these water quality parameters on aquatic life are discussed in Section II.E, Aquatic Biology.

1. Turbidity

a. General Discussion

Turbidity is caused by the presence of continuously suspended particulate matter such as clay, silt, glacial flour, organic matter, bacteria, and other microorganisms within a particular water body. It is not a measure of the concentration of these suspended solids, but a measure used to describe the opaqueness produced in water by the suspension. The concentration of the substances causes light to be scattered and absorbed rather than transmitted through water. Natural concentrations of suspended matter in streams are influenced by such factors as topography, geology, soil conditions, intensity and duration of rainfall, and the type and amount of vegetation within the drainage basin.

Streams may have considerable variation in suspended solid concentrations from day to day. In addition, there may be substantial differences in these concentrations in different stretches of the same stream. This may occur where material carried as bed load is thrown into suspension at a narrows or falls where the velocity increases, or at the confluence of other streams with different origins and fluvial characteristics.

b. Impacts

Effects of suspended particles vary with composition, particle size, and concentration, as discussed under Section II.E, Aquatic Biology. Typical effects of suspended particles include their

- Erosional properties on stream and river beds
- Abrasive action on aquatic plants and animals
- Ability through blanketing and sedimentation to influence substrate characteristics and/or plant physiological processes in lakes, streams, and estuaries
- Ability to reduce underwater light penetration by reflecting incoming solar radiation (This characteristic influences photosynthetic rate of plants and, indirectly, plant distribution.)
- Ability to provide additional substrate and surface locations on which bacteria and other microorganisms may grow

- Adsorption and/or absorption properties, including the ability to accumulate and concentrate various chemicals, among which are pollutants and pesticides
- Ameliorating properties on water temperatures (In general, suspended particles minimize water temperature fluctuations by absorbing and radiating heat at a slower rate than the surrounding water.)

A major adverse effect on aquatic organisms could occur if excessive concentrations of suspended matter were present at a time when the water is normally clear.

2. Toxic or Deleterious Substances

a. General Discussion

There are many substances dissolved or suspended in waters that may be toxic. These substances are those materials whose concentrations may adversely affect public health during the exercise of characteristic uses, or that may interfere with biological communities or populations to a degree which is damaging to the ecosystem. Metal ions, herbicide and pesticide residues, and fuels are typical substances which are toxic to aquatic life when discharged to water systems through human use. These substances may be contributed directly from waste discharges as in mining or manufacturing processes, or indirectly as in stormwater runoff from agricultural areas or cities. Seasonal fluctuations in water use and runoff amounts may cause concentration changes during the year, but continuous downstream transport tends to reduce levels in the upper reaches of streams while increasing them in major receiving basins.

b. Impacts

(1) Metals — Trace amounts of many metals occur naturally in water. However, when present in large amounts, they may constitute a very serious form of pollution because they occur in stable compounds and are not easily removed by oxidation, precipitation, or any other natural process. A characteristic feature of metal pollution is its persistence in time as well as in space for years after the pollution-causative operations have ceased. Changes in pH, dissolved oxygen, temperature, and turbidity are factors which can alter the toxicity of metals. At the present time, however, it is not possible to predict accurately the amount of total metal in any environment that may be lethal, biologically active, or contributory to toxicity.

Metal concentrations in excess of natural conditions are found in runoff waters from cities and urban areas — zinc from galvanized products, lead, chromium, and nickel from the operation and maintenance of motor vehicles. Metal concentrations in

excess of natural conditions are found in wastewater discharges. Aluminum, cadmium, copper, lead, mercury, chromium, zinc, and nickel are typical metals in wastewaters.

Metal concentrations in excess of natural conditions are found in leachates from freshly exposed rock surfaces (e.g. aluminum, copper, manganese, copper, iron, and sulfate). Lake sediments may also act as a reservoir for metal, which then enter into the water phase according to the solubility of the compound.

The effects of metal concentrations in excess of natural conditions on aquatic life are discussed in Aquatic Biology, Section II.E.2.

(2) Pesticides — Pesticides are chemicals, either natural or synthetic, which are used to control or destroy plant and animal life considered adverse to human society. Often they are categorized according to their use or intended target (e.g., insecticide, herbicide, fungicide), but their release in the environment presents an inherent hazard to many nontarget organisms. Some degree of contamination and risk is assumed with nearly all pesticide use. The risk to aquatic ecosystems depends upon the chemical and physical properties of the pesticide, type of formulation, frequency, rate and method of application, and the nature of the receiving system. The pesticides of greatest concern are those that are persistent for long periods and accumulate in the environment; those that are toxic to man, fish, and wildlife; and those that are used in large volumes over broad areas.

The major sources of pesticides in water are runoff from treated lands, industrial discharge, and domestic sewage. Significant contributions may also occur in fallout from atmospheric drift and in precipitation. In lakes the sediments may act as a reservoir from which pesticide is partitioned into the water phase according to the solubility of the compound, the concentration in the sediment, and the type of sediment. The effects of pesticides on aquatic life are discussed in Aquatic Biology, Section II.E.2.

(3) Fuels and Lubricants — Fuel, hydraulic fluid, and lubricant spills can be expected. Most spills would be small and associated with routine fueling and maintenance of construction equipment. The extent of water quality degradation would depend upon the following: (a) the type of fuel or lubricant, (b) amount spilled, (c) season, (d) location, and (e) success of remedial action. Should a major spill occur, there would be long-term adverse impacts on water quality; however, repeated small spills of fuels and lubricants may be as serious a water quality problem as a single large spill.

The spillage of fuels and lubricants in surface waters results in the release of water soluble substances or tainting substances which may be deleterious to aquatic life. Oils will also spread over surface waters, forming a thin film which will interfere with re-aeration and photosynthesis activity. The effects of these spillages are discussed in Aquatic Biology, Section II.E.2.

3. Dissolved Oxygen

a. General Discussion

Dissolved oxygen in natural waters is important both as a regulator of the metabolic processes of communities and organisms, and as an indicator of the balance between oxygen-consuming and oxygen-producing processes. Photosynthesis and physical aeration are the primary sources of oxygen in stream and lake waters. The contribution of each source is not equal and varies greatly with time of day, season, current velocity, wave action, stream or lake morphology, temperature, and biological characteristics. Under natural conditions, stream waters typically contain a relatively high concentration of oxygen, tending toward oxygen saturation. In lakes, the concentrations of oxygen may be uniform with depth or decrease with depth, depending on the season and mixing conditions acting within the lake.

b. Impacts

A number of factors operate to change dissolved oxygen concentrations in lakes and streams:

- Decreases in turbulent flow will reduce physical aeration. Conversely, turbulent action will increase aeration.
- Respiratory activities of plants and animals and oxidation of organic matter will deplete dissolved oxygen concentration in water bodies.
- Oxygen is replenished through plant photosynthesis.
- The solubility of oxygen in water varies inversely with temperature. Thus, raising of water temperature could result in loss of oxygen from streams.

The effects of dissolved oxygen changes on aquatic life are discussed in Aquatic Biology, Section II.E.2.

4. Acidity, Alkalinity, and pH

a. General Discussion

Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is the capacity of

the water and its constituents to neutralize or buffer the acidity. The pH of a water is a numerical value used as an indicator of the acidity or alkalinity.

b. Impacts

In most fresh waters, the pH falls within the range of 6.5 to 8.5. The pH scale extends from 0, very acidic, to 14, very alkaline, with a neutrality point which varies with temperature (pH = 7.0 at 25 degrees C). However, since pH depends upon minerals in the riverbed and input from the surrounding watershed, considerable variation from neutral pH may be encountered under natural conditions. Changes in the pH for a given water could be caused by the entry of strongly acidic or basic substances. The effects of changes in pH values on aquatic life are discussed in Aquatic Biology, Section II.E.2.

5. Temperature

a. General Discussion

Temperatures of surface waters in Alaska vary from 0 to 20.5 degrees C as a function of latitude, altitude, season, time of day, duration of flow, depth of water, and many other variables. The agents that affect temperature are so numerous that it is unlikely that two bodies of water, even in the same latitude, would have exactly the same thermal characteristics.

b. Impacts

Because significant temperature changes may affect the composition of an aquatic or terrestrial community, induced changes in the thermal characteristics of an ecosystem may be detrimental. Therefore, a "natural" seasonal cycle should be maintained, annual spring and fall changes in temperature should be gradual, and large unnatural day-to-day fluctuations should be avoided. Deviations from "natural" water temperatures can be caused by the following actions:

- Deforestation (more temperature fluctuations and greater temperature extremes)
- Stream channelization (depending on local conditions, can either increase or decrease temperature)
- Impoundment of flow water (generally increases temperature)
- Deep water releases from large reservoirs (decreases temperature of receiving waters and increases temperature in reservoir)

- Heated effluent from waste discharges or facilities utilizing water as a cooling (increases temperature)

The latter two actions will cause rapid thermal changes. The effects of changes in thermal characteristics of water bodies on aquatic organisms are described in Aquatic Biology, Section II.E.5.

6. Nutrients

a. General Discussion

Chemicals necessary to the growth and reproduction of rooted or floating flowering plants, ferns, algae, fungi, or bacteria are considered to be nutrient chemicals. All these chemicals are not yet known, but those that have been identified are classified as macronutrients, trace elements or micronutrients, and organic nutrients. The macronutrients are calcium, potassium, magnesium, sodium, sulfur, carbon and carbonates, nitrogen, and phosphorus. The micronutrients are silica, manganese, zinc, copper, molybdenum, boron, titanium, chromium, cobalt, and perhaps vanadium. Examples of organic nutrients are biotin, B₁₂, thiamine, and glycylglycine (EPA-R3-73-033, March 1973).

b. Impacts

There is a natural, gradual, and steady increase in external nutrient supply throughout the existence of a water body; however, artificial or cultural enrichment will result from increased nutrient addition through human activity. The effect of nutrient addition to water bodies is discussed in Aquatic Biology, Section II.E.6.

7. Coliform Bacteria

a. General Discussion

Bacteria are microscopic unicellular organisms, typically spherical, rod-like, or spiral and thread-like in shape, often clumped into colonies. Some bacteria cause disease; others perform an essential role in nature in the recycling of materials (for example, by decomposing organic matter into a form available for reuse by plants).

b. Impacts

Fecal coliform bacteria are present in the intestines or feces of warm-blooded animals. The occurrence of these bacteria in water is regarded as the single most important indicator of public health hazard from infectious agents. The survival of coliform bacteria in natural waters increases with decreasing temperatures. Accordingly, any

accidental discharge of sanitary waste materials into water could have long-lasting effects on human uses, since it would be possible to ingest live pathogenic organisms if untreated surface water were used for drinking purposes.

8. Water Movement

a. Surface Waters

Precipitation in the form of rain or melting snow drains land surfaces into small depressions and through natural valleys to form creeks, small streams, and ultimately, large rivers. The amount of water reaching a river channel depends on the precipitation, topographic relief, soil character, permafrost, and amount of vegetation in the drainage basin. All of these variables are water-dependent and vary dramatically within each basin and from season to season.

Temperature and the presence of permafrost cause wide fluctuations in stream flows and are not appreciably modified by groundwater recharge or storage. The velocity and turbulence of water movement are among its most important environmental characteristics; for example, plants and aquatic organisms depend upon water movement to deliver materials for their nutrition and respiration. The continuous flow of stream waters is the dominant characteristic distinguishing streams from lakes and ponds. However, water moves vertically and horizontally in lakes and ponds from wind action and the breakup of thermal stratification.

b. Groundwater

The direction of groundwater movement in the alluvial floodplain deposits of a river is generally parallel to the direction of stream flow, whereas the direction of movement in the adjacent terraces, alluvial fan deposits, and upland deposits is, in general, parallel to the surface slopes. The direction of movement in confined zones within the alluvium or bedrock aquifers, and within fracture or joint systems within bedrock, is independent of surface features. Ground temperature changes and the presence of permafrost can also cause wide fluctuation in groundwater movement and its recharge.

In general, the movement of water is cyclical, without permanent sources or sinks. However, a pollutant may enter at any phase of the cycle and be transmitted within that phase or other phases.

D. TERRESTRIAL BIOLOGY

1. General Introduction

All engineering actions affect vegetation and wildlife in several basic ways. Foremost is the quantitative and qualitative shift in species composition that occurs directly from the engineering action. In animals, shifts in density and distribution may additionally occur, indirectly, from the social dislocation of animals. For some species and in certain localities of Alaska, species shifts may result in genetic changes of the indigenous plants and animals. These three general results occur regardless of the engineering action and frequently occur simultaneously or are sequentially interrelated. Implications of these three impacts are discussed below.

a. Quantitative and Qualitative Shift in Species Composition

Engineering actions, be they temporary or permanent, will impact plants and wildlife. The specific impacts, however, are determined by the characteristics of each action including location, size, duration, season, and equipment used. Structural changes in the vegetation will result in "setting back" the state of a natural successional community to that of an earlier stage. The resulting temporary or permanent shift will be reflected in changing animal populations. Environmental and vegetative community factors are often drastically changed as cover vegetation is removed. Open clear-cut conditions are inductive to the development of a rich herbaceous layer, whereas intermittent and small openings in the canopy result in revegetation by indigenous tree species. Food and cover for many species are more abundant during earlier phases of succession than after the forest has formed a canopy.

Because each animal is characterized by a specific ecological niche, or is best adapted to a specific habitat, the horizontal and vertical dimensions of a plant community are extremely important. Bird species diversity, for example, has been correlated with foliage height diversity (MacArthur and MacArthur, 1961). Foliage height apparently represents some aspect of environmental complexity that allows birds to specialize on a particular part of the habitat. In fact, many animals besides birds restrict their activities to different levels within a forest; some feed on the ground, others feed among understory vegetation, and some restrict their activity to the upper parts of the canopy. Therefore, when habitats are changed to fields and marshes, which are structurally simpler, opportunities for within-habitat specialization decrease. For birds, this has been demonstrated by Cody (1968). The direct relationships between species diversity to stability and resilience to perturbations are complex and have been argued on theoretical grounds and with some empirical data. Nevertheless, in general, it does appear that complex and diverse environments characterized by complex food webs are more stable than simpler ones.

Perhaps the most direct and serious influence on plant and animal communities results from direct harvest of plant and animal resources. Timber cutting and hunting may quickly and dramatically change the species composition of an area or may subtly influence plant and animal characteristics over many years. Selective animal harvesting to a large extent determines population characteristics of subsequent generations. Quota, sex, and size of harvestable populations determine the age structure of the remaining population. Continual cropping of the largest (and frequently dominating) individuals may result in populations characterized by smaller (i.e., younger) and less experienced animals which, because of their inexperience, may be more susceptible to predation. Hunting, however, is also a tool by which wildlife can be maintained at a level the habitat can sustain. Periodic shortages in quantity and quality of food cause death, starvation, and migration, and hunting may alleviate these natural limitations.

Other forms of recreation may seriously impact terrestrial organisms. In spring and other critical periods, all-terrain vehicles may severely damage vegetation and destroy soil characteristics, thereby altering the vegetative composition of a region and/or the habitat for wildlife. Late winter snow machine use, if it occurs when ungulates give birth or at other critical periods in their life cycle, will also be detrimental to wildlife. It is at this time that energy must be preserved for survival and not wasted because of harassment by humans.

b. Social Dislocation of Wildlife

Engineering actions may disturb certain animals to such an extent that their social organization is altered. Harassment of animals, either directly by humans or indirectly through noise and other pollutants from machines, may result in the social dislocation of several species. For example, the continual disturbance and subsequent dispersal of musk-ox herds by helicopters exposes these animals to increased predation (Weeden and Klein, 1971). Mountain sheep have abandoned part of their range after disturbance and reoccupation of abandoned range is very slow. Caribou also are influenced by human activity that causes a disturbance in social structure. Seasonal caribou migrations are maintained by the older (and usually female) animals which return to the calving grounds that have been previously used. Therefore, the adverse impacts resulting from man's engineering actions described must take into account the behavior of such social animals and assess the significance a loss of these animals will have on the total population.

c. Genetic Changes in Species

Frequently, engineering actions result in plant communities and wildlife populations that are smaller and isolated from each other. In other cases, engineering actions (e.g., road construction, power lines) provide habitat along which plant and animal species

may migrate and extend their range, often times penetrating through otherwise unfavorable habitat.

Smaller size and increased isolation of plant communities tend to prevent the easy exchange between members of one stand with those of another. Apparently, cross-pollination is affected by a fractionalized environment in which outcrossing may be successfully limited. Seed dispersal and successful establishment of species may also be hindered by intersite vegetational and other barriers. The genetic implications of these limitations are extremely important. In isolated stands, "opportunities for inward migration are smaller and nonexistent" (Curtis, 1971, p. 515). Random gene fixation may increase, especially as isolating mechanisms increase. Specifically, genetic drift — one of the most important forces in evolutionary changes in small populations — is more likely to be an important factor in populations founded by a small group of colonists (Mayr, 1942) and in small isolated habitats.

The genetic effects of insularity on animal populations were reviewed by Simberloff (1974) and Simberloff and Abele (1976) and have been shown to parallel those predicted for plants. Small, constantly inbreeding populations eventually fix fewer genes and lose the rest through genetic drift. On the other hand, engineering actions and general impacts, in many cases, result in environmental and site changes that are conducive to dispersal and therefore to a mixing of gene pools. In addition, isolated islands resulting from man's activities are frequently utilized by colonizing species to extend their range. This has clearly been demonstrated for many introduced species which are associated with and distributed by humans. In remote locations far from their normal range, these introduced plant species grow and reproduce successfully, especially if they colonize areas in which their associated predators and diseases have not been established. In many cases, they are stronger competitors and exclude endemic populations.

The genetic implications described for plants also pertain to animals. Inbreeding in isolated populations also results in the loss of genotypic diversity because of genetic drift. In addition, colonizing animal pests that are associated with human activity often exhibit the ability to compete more successfully than endemic populations. The introduction of rats and fox on the Aleutian Islands is a fine example of colonizing and competitive introduced species that can be detrimental to endemic bird and animal species. Insect pests and disease also are readily and often unknowingly distributed by humans. The detrimental effects of vicarious introduced pests are often not apparent until populations have become well established and control measures are difficult and expensive to implement.

All engineering actions would be expected to significantly affect the species composition at the location that the activity is taking place. Social disorganization and genetic changes would also be affected; however, the importance of engineering impacts on

these two parameters is difficult to ascertain because they are dependent on species characteristics, including number of individuals in the population, location of species, and life cycle phenomena.

In addition to the impacts that are expected to occur for every engineering action, there are some impacts that are specific for each engineering action. For example, iron ore processing is expected to produce certain air pollutants, whereas gold mining will produce others. Therefore, a discussion of specific effects that may result from one or more specific engineering actions follows.

2. Effects of Vegetation Removal

a. Primary Production and Energy Flow

The clearing of vegetation will result in the removal of energy-rich material from the site. Regardless of vegetation type, the removal of plants will decrease the total energy represented by their biomass and in addition will remove the annual productivity attributed to their photosynthesis. The removed biomass and concomitant annual production will no longer be available to microbial soil-forming processes (e.g., nitrification, humification) or to animals that directly or indirectly depend on this vegetation for food and/or shelter.

b. Soil Water Balance

Removal of vegetation can decrease the water table elevation by creating increased runoff and thereby decreasing percolation through the soil to the aquifer. Conversely, clear-cutting and removal of vegetation decrease natural transpiration and may thereby increase the amount of water percolation into the soil, which can elevate an aquifer. The particular effects of vegetation removal on the soil water balance are dependent on the site vegetation and the physiographic characteristics of a site's slope and aspect. For example, in seasonally wet locations, a reduction in transpiration may create swampy areas from a perched water table.

c. Successional Sequence

The removal of vegetation frequently will alter the successional sequence of a site. Site geography, elevation, and seed availability will, to a large extent, determine the early successional pioneer species that generally colonize cleared areas. The reversion to early successional status of a site, however, may or may not be beneficial, depending on land use planning objectives.

d. Microclimatology

Clearing an area will remove the climatologically ameliorating vegetation. Vegetation removal will specifically alter the effects of solar radiation, albedo, emissivity, wind speed, and other microclimatological characteristics of the site, resulting in a denuded site characterized by extremes in light and temperature. In addition, the new environmental characteristics affect the physical and chemical structure of the exposed soil. The permafrost regions of Alaska are especially sensitive to these influences.

e. Soil Characteristics

Vegetation removal results in reduced protection against erosion, landslides, and rapid runoff. The risk of this damage is greatest when removing vegetation on steep slopes and in permafrost areas, where flash floods may frequently occur. In addition, clearing of vegetation increases soil damage by accelerating the decomposition of the humus layer, which is generally essential to both the chemical and physical genesis of soil. In many cases, clearing is accomplished by using heavy machinery which compacts the soil and is generally deleterious to the site.

f. Perimeter Species

Removal of vegetation from one region may indirectly affect the vegetative composition in adjacent areas. The influence may be either direct, as when trees are removed from a region and thus influence the seed source and recolonization of another region, or indirect, as exhibited by wind throw areas that occur in remaining surrounding trees after removal of part or all of the vegetation.

g. Fire Hazard

Vegetation removal may, in certain localities of Alaska, increase the fire hazard. Fire is a real possibility, especially in those areas where the vegetation is cut but not completely removed, such as the slash remaining after a logging operation.

h. Insect Population Dynamics

Another important result of clearing is the establishment of favorable environments for some insects. Many insects adapt or live within environments characterized by specific vegetation types, drainage and moisture regimes, and soil properties such as temperature, pH, texture, and chemical composition. Incomplete removal of vegetation from a cut area may encourage insect outbreaks such as those caused by bark beetles.

i. Fungal Diseases

Vegetation, especially forests, is subject to fungal diseases. Decay caused by heart and root rotting fungi is common in the southeast region, and probably other regions, of Alaska. Fungi occur naturally as trees mature. In many cases, disease and fungal infections in trees increase because of climatic or man-caused stresses. For example, several fungal species frequently occur in injured tree tissues damaged by heavy construction or logging equipment. In other cases, compaction of soil by heavy equipment may injure or otherwise stress the roots of trees, causing the tree to be more susceptible to attack. Slash that includes infected cull material discarded after an engineering operation also may spread decay to the remaining healthy vegetation. Infections frequently occur in scars from windthrown or other falling trees, and engineering actions that increase the likelihood of this type of damage will be harmful to the vegetation.

j. Food and Shelter for Wildlife

Removal of vegetation frequently reduces the food and shelter of birds and mammals, and therefore the carrying capacity of a region. Permanent loss of habitat will result in displaced birds and animals that may find suitable unoccupied habitat or will compete with members of their own or other species for other available habitat.

k. Landscape Dissection and Edge Effects

Engineering actions and their eventual results in many cases dissect or break up vegetation types, which then become characterized by a mosaic of community and species types. Excluding the Alaskan migrants, the ranges of animal species differ and generally vary from a few acres (snowshoe rabbit) to several square miles (moose) to many square miles (wide-ranging bear and wolves). Each species depends on free mobility and access to habitat that meets all of their requirements. The integrity of these home ranges is necessary for the livelihood and success of many Alaskan species. On the other hand, species such as deer, moose, and grouse are classified as "edge" species, requiring openings in forests, early stages of forest succession, and heterogeneous herbaceous vegetation. These conditions frequently result from man's activities, and therefore an increase in these animal species may be expected. Extensive stands of single vegetational communities, frequently characterized by few species, do not support high populations of wildlife; however, these communities may be important to large carnivore species. Dissection, fractionalization, and irreparable changes to the land may lead to local or regional extermination of plants and animals, especially those that are considered endangered and threatened. Once their population numbers fall below the level of effective reproduction, these plants and animals become extinct.

Table II-XII lists the general attributes that are characteristic of early and mature developmental stages of most ecosystems. Engineering actions that drastically remove vegetation or substantially alter the site will adversely affect vegetation and can be expected to cause corresponding changes in ecosystem attributes.

3. Effects of Atmospheric Pollutants

a. On Plants

Vegetation in many cases is more sensitive to air contaminants than animals. Among the pollutants that are known to extensively harm plants are sulfur dioxide, hydrogen fluoride, and ethylene. Plant damage caused by constituents of petrochemical smog, especially ozone, peroxyacyl nitrates, and higher aldehydes is relatively well known. Nevertheless, air quality criteria and standards based on the effects of pollutants on vegetation are nonexistent. High concentrations of most pollutants are known to cause acute damage to tissues, but limited information is available on reduction in crop growth and productivity, and very little on chemical and physical changes in plant cells and on interference with plant enzyme systems. The effects of pollutants on vegetation at various levels of light, humidity, temperature, and soil, as well as the change in plant susceptibility with life form and age, also have not been adequately assessed. The following discussion of air pollutants and their effects on vegetation was compiled to highlight general vegetation/atmospheric pollution interactions. Specific effects should be assessed at each site. Much of the following data were published by the American Chemical Society (1968).

(1) Carbon Monoxide — Carbon monoxide has not been demonstrated to produce adverse reactions in higher types of plant life at concentrations which produce loss of consciousness or death in animals. The possible effects of high carbon monoxide levels within the soil have not been thoroughly investigated, but significant impacts on vegetation and microorganisms at ambient levels are unlikely.

(2) Hydrocarbons — Hydrocarbons primarily originate from the incomplete combustion of gasoline. Ethylene apparently is the only hydrocarbon known to have adverse effects, and in high concentrations may cause abnormal leaf growth; the abscission of leaves, flower buds, and flowers, and inhibition of growth. For example, concentrations of a few parts per billion are extremely damaging to orchids, whereas slightly higher levels adversely affect the growth of tomatoes.

(3) Nitrogen Dioxide — High and continuous dosages (0.25 ppm for 8 months and 0.5 ppm for 35 days) of nitrogen dioxide have been shown to affect leaf abscission, chlorosis, and the yield of naval oranges. One ppm for 8 hours will produce significant growth reduction, expressed as fresh and dry heights, with no visible lesion damage.

**TABLE II-XII. A TABULAR MODEL OF ECOLOGICAL SUCCESSION:
TRENDS TO BE EXPECTED IN THE DEVELOPMENT OF ECOSYSTEMS**

Ecosystem Attributes	Developmental Stages	Mature Stages
Community Energetics		
Gross production/community respiration (P/R ratio)	Greater or less than 1	Approaches 1
Gross production/standing crop biomass (P/B ratio)	High	Low
Biomass supported/unit energy flow (B/E ratio)	Low	High
Net community production (yield)	High	Low
Food chains	Linear, predominantly grazing	Weblike, predominantly detritus
Community Structure		
Total organic matter	Small	Large
Inorganic nutrients	Extrabiotic	Intrabiotic
Species diversity — variety component	Low	High
Species diversity — equitability component	Low	High
Biochemical diversity	Low	High
Stratification and spatial heterogeneity (pattern diversity)	Poorly organized	Well organized
Life History		
Niche specialization	Broad	Narrow
Size of organism	Small	Large
Life cycles	Short, simple	Long, complex
Nutrient Cycling		
Mineral cycles	Open	Closed
Nutrient exchange rate, between organisms and environment	Rapid	Slow
Role of detritus in nutrient regeneration	Unimportant	Important
Selection Pressure		
Growth form	For rapid growth (r-selection)	For feedback control (K-selection)
Production	Quantity	Quality
Overall Homeostasis		
Internal symbiosis	Undeveloped	Developed
Nutrient conservation	Poor	Good
Stability (resistance to external perturbations)	Poor	Good
Entropy	High	Low
Information	Low	High

Source: Odum, 1969

(4) Sulfur Dioxide — Sulfur dioxide will cause damage to vegetation at concentrations of 1 ppm for 1 hour or 0.3 ppm for 8 hours.

(5) Hydrogen Sulfide — No harmful effects on plants at relatively high concentrations.

(6) Hydrogen Fluoride — This inorganic gas, from industrial processes such as aluminum processing, is extremely toxic to some living organisms and is likely to be an acute problem wherever materials containing fluorides are processed. It is taken up from the air by nearly all plants, and certain species are especially sensitive, being damaged by concentrations as low as 1 part per billion. Vegetation may remain unaffected but still concentrate fluorides, resulting in toxic levels in forage and leafy vegetables. When forage crops containing 30 to 50 ppm of fluoride measured on a dry weight basis are regularly consumed over a long period, the teeth and bones of livestock (cattle) may show changes; however, the extent of this effect depends upon age, nutritional factors, and the form of the fluoride ingested.

(7) Photochemical Oxidants — Many types of plants are sensitive to photochemical air pollution. (See Section II.A.2.) Ozone injury to leaves in sensitive species will occur after exposure to 0.03 ppm for 8 hours, and injury has been reported after 4 hours of exposure at 0.05 ppm.

(8) Particulates — Particulates generally are detrimental to plants when they plug leaf stomates, thereby preventing the exchange of gases necessary for photosynthesis, respiration, and transpiration. A more important and unique effect of particulates, especially in cold and snow-covered Alaska tundra environments, is their influence on the reflective properties of snow. Snow covered by fine sand, dust, and soot absorbs radiation, accelerates snowmelt, and hastens growth and reproduction of species, often to their detriment. Prematurely developing plants are more vulnerable to adverse weather effects and frequently succumb to unexpected or abnormally cold temperatures. Apparently, the vegetative composition paralleling oil pipeline supply roads of arctic Alaska has been gradually changing in response to the perturbations caused by vehicular traffic dispersing particulates along the route (Ugolini, personal communication).

b. On Wildlife

Too little information is available regarding the effects of atmospheric pollutants on animal species to specify air quality standards for wildlife and/or the effects of pollutants on wildlife. In many cases, information is extrapolated from man to animal. In other cases, effects have been established only for laboratory animals. Neither method pinpoints the influence of air contaminants on wildlife. Nevertheless, the general trend observed may be used to clarify, to some extent, the general effect of atmospheric

contaminants on wildlife. Supportive data for the following paragraphs were documented by the American Chemical Society (1969).

(1) Carbon Monoxide — Carbon monoxide has a great affinity for the oxygen molecule to form carboxyhemoglobin. Hypoxia, or diminished availability of oxygen to the cells of the body, results in animals that are exposed to high concentrations of carbon monoxide. The effects of various concentrations of carbon dioxide on human health have been established and, although extrapolation to wildlife populations depends upon the characteristics of individual species, the general physiological effects demonstrated for humans would also occur in most animals. The level of human protection against carbon monoxide poisoning would adequately protect the wildlife of an area.

(2) Hydrocarbons — The effects of hydrocarbons on wildlife species have not been adequately determined.

(3) Nitrogen Oxide — Nitrogen oxide in humans and test animals, including mice and rats, has shown that high nitrogen dioxide levels increase the susceptibility to respiratory infections and result in acute respiratory diseases in humans (e.g., emphysema, bronchitis) and pneumonitis, alveolar distention, tachypnea, and terminal and bronchiolar hypertrophy in mice and rats.

(4) Sulfur Dioxide — Sulfur dioxide is extremely irritating to upper respiratory tracts in concentrations of a few parts per million. In addition, droplets of sulfuric acid carry absorbed sulfur dioxide far deeper into the respiratory system than the free gas above penetrates, thus spreading the effect of this irritant. (Hydrogen sulfide in the open atmosphere rarely exceeds the level of mere nuisance.)

(5) Hydrogen Sulfide — Hydrogen sulfide at levels of 1 ppm for 1 hour may cause sensory irritation to animals. At several hundred ppm, acute sickness, neurotoxicity, and death may occur. However, it is unlikely that these levels are reached in community air pollution.

(6) Hydrogen Fluoride — Concentrations of 2 to 5 ppm have resulted in desquamation of the skin. Mucous membrane irritation also occurs from hydrogen fluorides, but quantitative data are not yet adequate to establish standards.

(7) Photochemical Oxidants — Photochemical oxidants primarily affect the respiratory system of animals. Exposure to extremely high levels for several hours produces hemorrhage and edema in the lungs and nasal, throat, and eye irritations. Lower concentrations for 0.12 week have not produced any apparent ill effects in humans and are not expected to adversely affect wildlife. Ozone, however, at 1 ppm for 8 hours daily for 1 year has produced bronchiolitis and fibrositis in rodents.

(8) Particulates — Particulate air pollution (e.g., dust, soot, beryllium, lead, asbestos) present in large concentrations has been known to cause injury to the respiratory system. The extent of injury, whether temporary or permanent, and the possible secondary effects with the transportation of particulate matter within the body are uncertain. Particulates derived from burning material may also affect animals.

4. Effects of Pesticides

a. On Plants

(1) Accumulation of Residues — Pesticide residues that build up in the soil conceivably are injurious to crops grown in later years. Factors affecting pesticide accumulation are the pesticide used, soil type, soil moisture, soil temperature, cover crops, soil cultivation, mode of application and formulation, and microbial degradation. Available data indicate that pesticides persist longer in soils that are organic, dryer, and colder, indicating that pesticides in Alaska may be long-lived. Residual arsenic pesticides (e.g., those used on commercial apple orchards) are generally confined to the top 6 to 8 inches of the soil and do not harm established trees where roots extend below that level. The roots of young trees do not reach that deeply and have been injured or killed by residue arsenic.

(2) Absorption by Crops — Pesticide residues may be absorbed by crops and native vegetation. In Wisconsin, aldrin and dieldrin concentrations in cucumbers have been shown to be 2 to 6 percent of the concentrations in the soil. Carrots exhibit 22 to 80 percent of the soil concentration (American Chemical Society, 1969).

(3) Contamination of Surface Waters — Pesticide residue is either in continuous transport on suspended particulate material or in bottom sediments. Accumulation in plants can occur and transfers to feeding organisms can subsequently occur.

(4) Toxicity to Nontarget Plants — Pesticides, when used in agriculture and forestry, may frequently be toxic to nontarget plants. Crops have been harmed by airborne weed killers, particularly of the phenoxy (2,4-D) type, that drift long distances from the point of application (American Chemical Society, 1969). Ester types are especially volatile and may drift for miles and still damage sensitive crops. The effect of airborne pesticides on noncrop and native species has not been determined. One specific aspect that needs considerable study is the effect of smoke from burning materials that are contaminated by pesticides.

b. On Animals

Pesticides have been used for at least 20 years, but studies on their effects on wildlife and their environment have begun only recently. In general, studies have shown that

- Residues are common both in wildlife and habitat.
- Species that depend on aquatic or wetland habitats are more heavily exposed to insecticide residues than those on dry terrestrial habitats. The dry-land carnivorous species, however, are the exception, as exemplified by predatory birds.
- Moderate to high levels of residues found in the tissues of some species probably result from direct exposure rather than from the biological concentration associated with the food chains.

Specific effects and the physiological base for the differing responses in differing species to pesticide residues are still essentially unknown. It has been shown, however, that relative immunity to residues can be acquired by vertebrates that live in heavily contaminated environments and reproduce selectively for resistance. Specific effects of pesticides are discussed below.

(1) Soil Productivity — Excessive pesticides may have harmful effects on living organisms in soil, which in turn are part of and function in soil genesis, thereby directly affecting soil productivity.

(2) Concentrations in Food Chains — The effects of pesticides in water may be a serious hazard, especially if the residue is stable and concentrated in the food chain, as has been shown for residues of chlorinated hydrocarbons in the conterminous United States (e.g., DDT and DDD in lakes). One such classic example is found in the plankton/small fish/predaceous fish/predaceous bird and mammal food chain. Contamination initially occurs with small quantities of DDD or DDT being absorbed by algae, phytoplankton, and zooplankton, which are then concentrated at each step of the food web and eventually are expressed in detrimental quantities within avian populations such as peregrine falcons, hawks, and eagles and marine mammal populations such as seals and walrus.

Serious toxicity and symptoms of poisoning may not appear until the final trophic level and are most frequently lethal to the immature individuals. With regard to such populations as peregrine falcons, hawks, and eagles, nests are built and eggs laid, but no young are fledged. This is physiologically based and caused by concentrations of pesticide. Residues in lipid and fatty acid tissues alter the normal hormonal balance and cause the breakdown of estrogen in birds, which then affects the blood calcium level and in turn adversely affects the adult and its unhatched egg. The eggs may either fail to develop or may be thin-shelled and brittle and break prior to chick hatching. In seals and walrus and other marine mammals, pesticide residues also concentrate and may be transferred to humans if the affected animal is eaten.

(3) Toxicity to Nontarget Organisms — Pesticides frequently are toxic to nontarget organisms. The hazard to nontarget organisms depends partly on the nature of the exposure, such as inhalation, ingestion, or contact with the skin. The hazard to mammals is generally greater because pesticides are directly absorbed from the lungs more quickly and completely than from the digestive tract or through the skin. The degree of respiratory hazard cannot be evaluated until more is known about the concentrations of pesticides and their breakdown products in the air at various times and places. In general, the concentrations actually reported for pesticides in the air, except in the immediate vicinity of the point of application, are not high enough to present an acute hazard to most animals during short periods of exposure. However, cattle have been killed by TEPP (tetraethyl pyrophosphate) when air inversions held a cloud of dust in a restricted area for 2 hours (Quimby, 1965).

5. Effects of Solid Waste

Solid waste generally refers to rubbish, refuse garbage, and other material that is discarded actively or inadvertently as a by-product of man's activity. Rubbish includes combustible items such as cartons, boxes, paper, grass, plastics, bedding, and clothing; and noncombustible items such as ashes, cans, crockery, metal furniture, and glass. Garbage refers to waste resulting from growing, preparing, cooking, and serving food. Regardless of the term used, solid wastes result wherever man has stayed for any substantial time. Solid waste can be further characterized according to the physical and chemical makeup of the major constituents, as follows:

- Municipal Refuse — Complex heterogeneous substances produced and discarded by people throughout their lives. These substances include paper, garbage textiles, glass, metallics, and ceramics.
- Industrial Solid Waste — This generally includes nonferrous scrap metals, stones, bricks, etc.
- Construction Solid Waste — Material left after construction, including vehicle tires, detonating wire, fuel cans, barrels, unused poured cement, and numerous other substances characteristic of specific construction operations.
- Automobiles — Discarded automobiles are a major problem which does not fit neatly into any of the three preceding categories.

a. Removal of Space

Solid waste influences vegetation and animals by taking up space that normally exhibits plant communities or affords animal habitat. Sanitary landfills, especially near large urban centers, may occupy many acres of otherwise potential wildlife habitat.

b. Damage from Leachate

As a result of leaching from solid wastes, weathering (e.g., oxidation and biodegradation) may cause chemical changes and subsequently damage plant and animal species. Noxious and unpleasant gases may also be produced and may influence animal distribution.

c. Health, Aesthetics, and General Ecology

Waste disposal is frequently a health, aesthetic, and ecological problem. Inorganic wastes, including fuel cans, barrels, and detonating wire, may influence the behavior of animals by restricting the freedom of movement, or provide hazards to animals by ensnaring and otherwise killing them. Biological wastes also may be detrimental to animals. Grizzly bears, wolves, wolverines, gulls, ravens, and many other animals and birds scavenge in garbage pits and are sometimes destroyed wantonly because they pose a threat to humans.

An important consideration not directly pertaining to solid waste disposal or atmospheric pollutants is the accidental spillage of chemicals, oil, and other substances used in the construction process. Regionally, this impact may not be significant; however, localized sources may be detrimental to both plants and animals.

6. Noise Pollution

Noise pollution is frequently an important source of disturbance to wildlife. Although the effects of noise from aircraft, construction and drilling equipment, blasting, and other sources that occur with the various engineering actions are poorly documented, it may be assumed that during critical periods (e.g., breeding and calving) and in special environments (open, unprotected lakes and small valleys) noise will be detrimental to animal populations. Gallop, et al (1974) reported that during breeding there was a measurable reproductive failure attributed to disturbance. Sterling and Dzubin (1974) found that sea ducks vacate traditional molting areas when disturbed by aircraft. Gallop, Goldsberry, and Davis (1974) indicated that molting waterfowl alter normal behavior patterns, and with repeated exposure behavioral alteration would have detrimental effects on the population.

Data on ungulate populations indicate that habituation to disturbances may occur for some animals, including reindeer (Thompson, 1972), caribou (McCourt and Horstman, 1974), and Dall sheep (Thompson, 1972). However, in many cases the extent of impact varied with season and activity and generalizations should not and could not be made. Barren ground caribou, for example, were most influenced by aircraft noise during the post-calving season and least influenced during fall migration and summer movements.

Until rigorous tests are established that will determine the influence of aircraft, compressors, and other equipment at all stages during the life cycle of birds and mammals, noise pollution should be minimized as much as possible.

7. Monoculture

Simplification of communities often results in population outbreaks. By producing monoculture, man reduces the diversity of primary producers, which almost always results in decreasing diversity at higher trophic levels. Decreased plant and animal diversity frequently is associated with environmental instability in that population changes in one or a few species affect trophic interactions within all other species of an interrelated ecosystem. For example, in even-aged pure western hemlock stands, black-headed budworm infestations are more devastating than in uneven-aged mixed stands because it is easier for a pest to spread when the food resource is identical in nature (Harris and Farr, 1974). Diversity of plant species and age structure in certain cases may sometimes increase damage, especially for those pest species that require alternate hosts. Therefore, the potential detrimental impacts by pests (including economic loss) on agricultural and timber monocultures should be assessed prior to production. It is essential to understand the relation between pest infestation levels and potential crop loss.

E. AQUATIC BIOLOGY

Water quality parameters as discussed in Section II.C subsequently affect the aquatic biology and are further discussed in the following subsections.

1. Silt and Turbidity

The composition and concentrations of materials suspended in water are important because they influence light penetration, temperature, and other properties of water which affect aquatic life. Increases in silt and turbidity from human activity are more likely to affect aquatic life in waters which have minimal natural sedimentation.

a. Plants and Water Density

The growth of fixed and suspended aquatic plants can be limited by excessively turbid waters or by silt covering plant surfaces. Because silt particles absorb more sunlight than clearer waters, turbid water near the surface is warmed more rapidly, resulting in a density decrease which inhibits vertical mixing. This action reduces the rate of downward oxygen transfer, which may result in a change in the composition of biological communities. Some fish and invertebrates may be replaced by other species which require

less oxygen, or the increase in turbidity may reduce the density and diversity of the biological community.

b. Fish and Shellfish

The mechanical and abrasive action of particulate material is important to more advanced aquatic organisms such as fish and shellfish. Gills may become clogged and the respiratory and excretory functions of these organs may be impaired. Fish can survive relatively high concentrations of suspended matter (several thousand milligrams per liter of water) for short periods, but prolonged exposure for most species results in a thickening of the cells of gill tissue ("clubbed" gills), which interferes with respiration. Irritated gill tissue is also an avenue of infection for fungi and pathogenic bacteria. Salmon are more sensitive to turbid water than other fish such as carp and bullhead, which thrive in waters clogged with decaying vegetation and other organic material.

c. Fish Spawning

Excessively turbid water may limit successful spawning since some species of fish will not spawn in water with large amounts of suspended sediment. Spawning areas for salmon require loose gravel, which allows water and oxygen to reach the buried eggs. As rocks or masses of sediment are carried downstream, they may destroy or sweep away critical spawning areas. Silt deposits also may smother buried eggs by interfering with the percolation of water through the gravel.

d. Benthic Invertebrates

Silt deposited on the bottom of a stream may smother and destroy benthic invertebrates, which serve as the primary food source for developing salmonids.

e. Fish Migration

Some species, particularly salmon, will not move into streams with a high silt content and their migration patterns may be modified.

f. Contaminated Sediment

Suspended mineral particles have large, irregular surface areas to which toxic materials such as pesticides, heavy metals, and radioactive materials adhere. This property of silt particles is particularly important if it leads to an accumulation of toxic material in a limited area with the possibility of sudden release of these toxicants when sediments are disturbed. This characteristically occurs when contaminated sediments are dredged from harbors.

2. Toxic Substances

a. Physiological Effects of Heavy Metal Ions

Heavy metal ions may affect the gills of aquatic organisms, impairing respiration and resulting in slow death. Enzyme processes may also be interrupted and eggs may be prevented from hatching normally. The toxicity of some metals is directly related to water hardness and the pH is important in governing their solubility and ionic species in water. At a high pH, many metal ions combine with other materials and form insoluble compounds which precipitate. Other factors which influence the toxicity of metals are dissolved oxygen, temperature, turbidity, carbon dioxide, and inorganic salts.

b. Heavy Metal Ions in Sediments

Metals which have accumulated in sediments may exhibit extreme local and downstream toxicity when disturbed by natural or human processes.

c. Physiological Effects of Pesticides

Many pesticides, such as DDD and DDT, have low water solubility and are rapidly absorbed in animal lipids or suspended materials in the water. These dissolved chemicals may cause abnormal physiological changes to aquatic organisms or may result in impaired reproduction or development of the young.

d. Pesticides in Sediments

Pesticides which have accumulated in sediments may exhibit extreme local and downstream toxicity when disturbed by natural or human processes.

e. Pesticides and Toxicity

Most pesticides are degraded by metabolic and chemical processes in a relatively short time (e.g., malathion and methoxy chlor). However, some chemicals are extremely stable and degrade slowly or form persistent degradation products (e.g., dieldrin, endrin, and chlordane). Aquatic organisms then may accumulate these compounds by absorption from water or through eating contaminated food. The transfer of pesticide residues from prey to predator in the food chain results in the accumulation of residues in the higher trophic levels. Fish may survive high residue concentrations because the pesticide is incorporated into body fat, but residues concentrated in the eggs of mature fish may be lethal to the developing fry. Residues in fish may be directly harmful if stress causes body fat to be metabolized and releases the absorbed pesticide. Temperature changes may also affect the toxicity of pesticides.

f. Pesticide Long-Term Effects

Fish populations normally recover from pesticide exposure within a few months but, if the young of anadromous species are destroyed, future migrations to the area may be decreased. The recovery of aquatic invertebrates in heavily contaminated areas usually requires a longer period of time. If residues persist in bottom sediments, benthic organisms may be harmed even though water concentrations are low. Undesirable insect species may be the first to repopulate the area and the entire aquatic community development may be changed.

g. Other Toxic Substances

Additional substances which may be toxic to aquatic organisms include ammonia (NH_3), detergents, petroleum compounds, sulfides, and chlorine. The action of these substances will be discussed where applicable for a specific engineering action.

3. Dissolved Gases

a. Dissolved Oxygen

Any decrease in the level of dissolved oxygen may adversely affect the production of aquatic organisms. Most species of adult fish can survive at very low concentrations of dissolved oxygen but growth, activity, and embryonic development can be limited if oxygen is reduced below saturation. Salmon and other cold water fish generally require more oxygen than warm water fish. Normal development of salmon eggs requires a higher level of oxygen than other salmon life processes because the eggs are buried in gravel and are not exposed to all the oxygen in the water. Oxygen requirements of invertebrates and other aquatic species are generally compatible with fish; any reduction of oxygen saturation may decrease production.

b. Dissolved Gas Supersaturation

Excessive total dissolved gas pressure caused by natural or artificial mixing of water and air (supersaturation) is known primarily for its effects on the northwestern United States Columbia River salmon fishery, and is due to the extensive development of dams for hydroelectric power on this river. Anadromous fish may be affected as they swim through supersaturated water on their migration to or from spawning grounds. The effect occurs when the total gas pressure exceeds the hydrostatic pressure and the dissolved gases begin to come out of solution and form bubbles. Fish swimming in water under these conditions (from the surface to 10 feet for 130 percent saturation) may develop symptoms of gas bubble disease, as bubbles appear on the fish and then within the skin, on the roof of the mouth, and within the fins and abdominal cavity. Gas bubbles may also form behind the

eyes, causing distension of the eyeballs. Eventually, gas emboli in the blood may become large enough to obstruct blood vessels and cause death.

4. Acidity and Alkalinity

There is no optimum pH value for aquatic life but the pH ranges from 6.5 to 8.5 in most productive waters. Some regions have naturally soft waters with a low pH, resulting from the addition of tannic acid leached from trees. These waters are generally less productive and, although many species of fish can live in the acid water, they grow more slowly than those living in alkaline streams. The tolerance of fish to extreme pH levels varies with temperature, dissolved oxygen, prior acclimation, and hardness.

a. Addition of Acids or Alkalinities

The addition of acids or alkalinities to water may be harmful, not only by producing acid or alkaline conditions but also by increasing the toxicity of other materials in the water. For example, acidification of water may release free carbon dioxide, which exerts a toxic action in addition to that of the lower pH. Alkaline conditions may cause the formation of ammonia in quantities which may be toxic. Specific causes and effects of alteration of acidity and alkalinity are treated in the impact analysis sections of this report. Of particular importance are the effects caused by surface mining, as discussed in Section IV.K.

b. Nutrients and Productivity

The availability of many nutrients varies with pH; solubility changes in iron or trace metals may alter the production of the entire aquatic community.

c. Carbonate Buffering and Productivity

The addition of mineral acids interrupts the carbonate buffering capacity of water, which reduces fluctuations in pH and forms the carbon reservoir for photosynthesis. Since the exchange rate between atmospheric carbon dioxide and water is limited, the carbonate buffering system is closely correlated to the productivity of an aquatic system. Any interference with the buffering system could reduce productivity proportionately.

5. Temperature

The composition of aquatic communities depends largely on the temperature characteristics of their environment. Organisms have upper and lower thermal tolerance limits, optimum temperature for growth, preferred temperatures, and temperature limitations for migration, spawning, and egg incubation. Temperature also affects the

physical properties of the aquatic medium including viscosity, ice cover, and oxygen capacity. Since the body temperature of most aquatic organisms conforms to the water temperature, the natural variations in water temperature create conditions that are generally above or below optima for particular physiological, behavioral, and competitive functions of the species.

a. Long-Term Temperature Changes

Long-term water temperature changes may affect aquatic organisms by inhibiting or altering the time of spawning or migration, egg or juvenile development, and growth, or by increasing disease susceptibility. The effects of these impacts may differ by species, resulting in a change in the structure of aquatic communities due to increased predation on the less adaptable species.

b. Dissolved Gases

Temperature changes also affect the amounts of atmospheric gases which can remain dissolved in the water. Very warm water contains limited oxygen, which in turn may limit swimming speed, thus increasing predation or decreasing the ability to obtain food.

c. Productivity

The addition of heat may alter aquatic communities and result in growths of nuisance organisms, provided other environmental conditions, such as nutrient availability, are satisfactory. Plankton growth has been stimulated in artificially heated lakes and excessive algae growths have occurred in the effluent channels of power stations. This plant growth may result in offensive odors and obstructed water intake systems, and the decomposition of algae may decrease the oxygen available for other organisms.

6. Nutrients

Although aquatic animals are not directly affected by the amount of nutrients in water, they may be indirectly influenced by the effects of these essential chemicals on plant growth. The addition of nutrients and their effects on a body of water is referred to as eutrophication.

a. Plant Productivity

Since plants vary in the amounts and kinds of nutrients they require, one species or a group of species may gain dominance over another group because of the variation in concentration of nutrients. The overabundant growth of aquatic plants may cause disagreeable odors or unattractive growth which inhibits human use of the water.

When the plants die, their decomposition may deplete oxygen supplies and result in fish kills.

b. Animal Productivity

Eutrophic lakes typically produce greater crops of fish than nutrient-poor lakes since more food is available for the detritus consumers and other aquatic organisms upon which fish feed. As long as nuisance blooms of algae and extensive aquatic weed beds do not hinder the growth of fish species, some enrichment may be desirable. Streams and estuaries, as well as lakes, may show symptoms of overenrichment, but there is less opportunity for nutrient accumulation because of the continual transport of water.

7. Exploitation of Fish Populations

Fish populations are naturally limited by environmental factors such as temperature extremes, rainfall intensity, stream flow, and predation which may vary the availability or accessibility of spawning sites, food, or migration routes. Increased human activity results in increased sport, commercial, or subsistence fishing, which may decrease the population of mature fish to a level which can no longer sustain the species. The anadromous salmonids of Alaska are particularly susceptible to fishing pressure. An increased harvest may decrease the numbers of fish in a stream to a level which cannot withstand the natural variations due to extreme environmental conditions, and the entire stream population may be destroyed. Other aquatic and terrestrial systems which have adapted to annual salmon migrations may be affected if migrations are interrupted or significantly diminished.

F. SOILS

1. Introduction

The impacts of man's actions on soils are aptly expressed in the two statements that follow:

It is an irony of history that semi-desert conditions now prevail in much of the region once known as the Fertile Crescent. . . . Moreover, the earlier peoples had on the whole a higher standard of living than most of the present inhabitants. The degradations of the region came about almost entirely because of human discord and neglect. The ancient peoples had ingeniously developed the lands of the Fertile Crescent by intelligent use of meager water resources. . . . Then invaders laid waste to the region and a long decline set in. A succession of indolent and mutually intolerant people allowed the cisterns and reservoirs to fall into ruin, the irrigation channels and terraces to crumble, the trees to be cut down, the low vegetation to be destroyed by sheep and goats and the land to be scoured by erosion. [Garbell, 1965]

Hence, to correct these evils, it is necessary to remove the causes, which, for the most part, had their origin 100 years ago in the silting we now see. Other causes I will name are the great and frequent inundations and the huge quantities of refuse and mud which the mountain torrents and rivers are carrying and depositing at the present day in the lagoons, something unknown to antiquity. For then, both mountains and valleys were full of trees and vast forests, as a result of which in those times the rains, falling upon these woods, soon dispersed, and all the water descending directly was almost wholly absorbed by the dead leaves and the ground itself; that small portion that ran hither and thither through the forest, held back by the trunks and roots of the trees, turned into vapor, consuming itself almost completely in the ditches and gullies. . . . But at the present time, as the mountains of the exulted dominion have been ruined and despoiled of their clothing, the rains, finding nothing to restrain them, and the snows remaining exposed to the sun, fall precipitately, straight down upon the lower levels. Laden with great quantities of residual matter, they swell in the turbulent brooks and rivers to such an extent that each year, by the forces of this impact, they break dikes, lay waste the fields, destroy edifices, country homes, and sometimes even entire hamlets. . . . [Kittredge, 1608]

Traditionally soils have been considered to be the product of the five natural factors of parent material, vegetation, climate, topography, and time. However in recent years, soil scientists have established the importance of man as an agent creating soil change (Detwyler, 1971). Man-induced soil impacts which can be expected to occur in Alaska are described in the following paragraphs.

2. Accelerated Erosion

Actions that remove vegetation, mechanically disturb the soil, and/or alter hydrologic processes typically accelerate erosion. In general, such accelerated erosion results in loss of valuable land and decreased fertility and productivity of the area impacted, and may result in the necessity for primary soil succession (reestablishing soils) to occur.

3. Sedimentation

In conjunction with accelerated erosion is the deposition of the eroded materials in other environments. The soil material is characteristically moved by the agents of air or water. The deposition of the eroded material on other environments may be of positive or negative value. For example, periodic flooding and silt deposition on floodplains recharge the inundated areas with nutrients, resulting in a periodic natural fertilization process. On the other hand, silt deposition on gravel bars used by salmonids for spawning can smother eggs and destroy the area as a breeding area.

4. Mass Wasting

Actions which alter topography, drainage, and/or the stability of slopes (e.g., building loads) can result in the gravitational downhill movement of material (flowing waters excluded) called mass wasting (i.e., solifluction, soil creep, landslides, and avalanches). For a more detailed discussion of these impacts see *Natural Hazards in the Alaska Environment* (John Graham Company and Boeing Computer Services, Inc., 1975). Damage typically resulting from mass wasting is not subtle and includes loss of life and property, increases in erosion and sediment, and destruction of vegetation, as well as creating a blight on the visual and aesthetic character of an area.

5. Subsidence

Three forms of subsidence can be expected to result from development actions in Alaska: (a) subsidence due to thermal erosion of permafrost; (b) subsidence due to compression of soils, particularly organic soils and landfills; and (c) subsidence due to the withdrawal of subterranean fluids. Impacts include changes in topography and drainage, damage to structures, formation of water bodies, and flooding.

6. Compaction

Actions placing physical stresses on surface soils (e.g. compacting by heavy construction equipment) can result in compaction of some soils. Such compaction leads to a reduced ability of vegetation to regenerate and an increase in the impervious nature of the soils, with a subsequent change in groundwater recharge and runoff characteristics which can create erosion off site.

7. Alteration of Permafrost

The occurrence of permafrost establishes particularly sensitive and dynamic properties of the soil. Actions which alter this thermal equilibrium of the permafrost active layer system can lead to subsidence, erosion and sedimentation, and extensive mass wasting until the thermal equilibrium is reestablished. Small-grained soils with high ice content are the most sensitive and unstable.

8. Changes in the Biological, Chemical, and Physical Properties of the Soil

The soil is a component of the ecosystem which stores and releases essential nutrients and water to biotic systems and water to hydrologic processes. Many of man's actions result in changes in the ability of soils to store nutrients and water, and in the ability of soils to accept or release nutrients and water. Also, man's actions can remove or introduce water, nutrients, and other materials at changed rates, resulting in the depletion or

saturation of the soils with respect to these elements. Such soil changes are reflected in the interdependent hydrologic and biologic processes. Specific changes in the soil's ability to accept, store, and release nutrients and water typical to Alaska are as follows.

a. Soil pH

Soil pH can be changed by a number of man's actions including the introduction of mining spoils; the addition of lime, fertilizers, and pesticides; and the alteration of soil temperature. Changes in pH are reflected in the soil's ability to hold anions and cations and the ability of particular plants to efficiently remove nutrients from the soil. Small changes in pH result in conditions favorable to some species and inimical to others. Extreme pH values are toxic as shown in Figure 2-13.

b. Soil Temperature

Temperature and biochemical activity are directly related. Actions which remove vegetation generally cause an increase in soil temperature and may result in increases in chemical activity of the soil, decomposer activity, and depth to permafrost.

c. Soil Structure

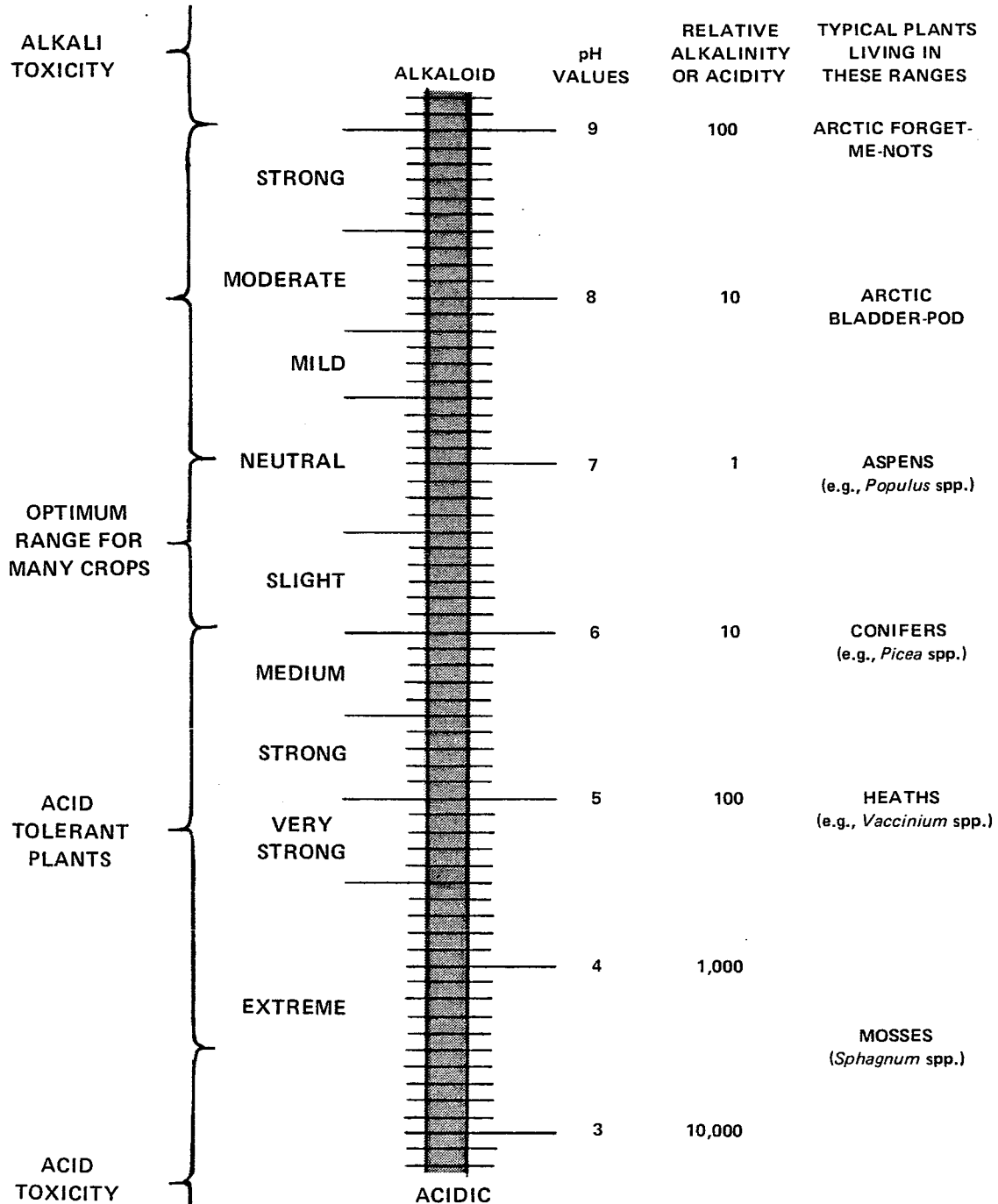
Compaction of some soils results in reduced space between soil particles, which can lower the air and water concentrations in the soil bulk. In addition, the infiltration ability of the soil is reduced, and aerobic microbial activity is hampered (e.g., phosphatizing and nitrifying bacterial action). Rain on denuded soils tends to form a surface slush which seals the soil pores, reducing infiltration and generating increased surface runoff and erosion.

d. Soil Fertility

Loss of soil through erosion is the most obvious means by which soils become infertile. Continued removal of soil nutrients (by such things as harvest of crops) at a rate greater than what is being generated by the soil system will lead to a reduction in soil fertility.

9. Covering of Soils With an Impervious Layer

Roads, houses, airports, etc., cover the soil surface with an impervious material which reduces the area's ability to absorb water. This reduced capacity for absorption may have secondary impacts on groundwater and runoff (e.g., increases stormwater runoff to flood stages). In addition, soils covered with an impervious layer are generally removed from biological production systems.



NOTES: Actual acidity or alkalinity changes 10 times, or 1000 percent, for each unit of pH; also, the point of direct acid toxicity is below the level of extremely acid soils.
Due to climatic stresses of Alaska, lethal limits are probably more severe than indicated.

Figure 2-13. pH and Soil Acidity or Alkalinity

G. INTERACTIONS OF PHYSICAL AND BIOTIC ELEMENTS

1. Introduction

Physical and biotic elements of the environment interact through food webs, precipitation, runoff, etc., to form ecosystems. Although climate and geology provide a setting in which ecosystems function, the movement of energy and material through space and time establishes the mechanics of an ecosystem. Even seemingly "simple" ecosystems, such as those of the Arctic, are very complex and incompletely understood.

To consider and describe all potential or even probable consequences of the selected actions on the biotic and physical systems comprising the ecosystems of Alaska is literally impossible. The basic reasons for this inability include (a) a general lack of knowledge concerning the mechanics of Alaska's many ecosystems and (b) the fact that all elements of an ecosystem are linked, and describing all connections and consequences would approach an infinite number of items. However, those impacts which are best understood and also judged to be significant are identified. Those impacts selected are on nutrient transfers, transfers of toxic substances, sediment transfers, water transfers, and migratory behavior.

2. Nutrient Transfers

Nutrient transfers from terrestrial to aquatic systems generally increase as human development activities are initiated. In conjunction with harvest, these transfers result in a loss of nutrients in terrestrial systems which results in a loss of fertility. In aquatic systems, these increased nutrient transfers generally result in increased nutrient concentrations and subsequent eutrophic effects.

a. Additions to Aquatic Systems

The problem of increased concentrations of nutrients in aquatic systems is compounded by fertilization in forestry and agricultural land use activities, which results in nutrients finding their way to aquatic systems and in human or animal waste placed in aquatic systems.

b. Removal from Aquatic Systems

Some aquatic systems are dependent on nutrients and other materials imported from external ecosystems. Reduction of nutrient inputs can result in reduced primary productivity and possible collapse of important fisheries.

c. Removal from Terrestrial Systems

Erosion, leaching, and harvesting remove nutrients from the soil. These nutrients require replacement if long-range productivity is to be maintained.

3. Transfer of Toxic Substances

All of the engineering actions under analysis generate a certain amount of waste material, which can contain various amounts of toxic materials. Table II-XIII shows some of the typically introduced waste pollutants, the environment into which they are generally discharged, the environment into which the pollutant is then transferred, and the general impact on flora and fauna. As shown, many of the potentially toxic materials are transferred from environment to environment. The transfers of such substances can occur through food chains, precipitation, runoff, and leaching or other mechanisms.

The 1972 amendment to the federal Water Pollution Control Act defined toxic pollutants. In July 1972, the Environmental Protection Agency designated the following 12 chemicals as toxic water pollutants: aldrin, dieldrin, endrin, DDT and its derivatives DDE and DDD, toxaphene, cadmium, mercury, cyanide, benzedine, and PCP (polychlorinated biphenyls). Chemicals which are under scrutiny for possible inclusion to the list are arsenic, selenium, chromium, lead, asbestos, sevin, zinc, chlordane, lindane, acridine, hydroquinone, orthochlorophenol, beta-naphthol, alpha-naphthol, beryllium, nickel, antimony, heptachlor, camphor, methyl parathion, parathion, and di-n-butyl phthalate (Council of Environmental Quality, 1975).

4. Sediment Transfers

Development actions traditionally increase the transfer of sediment from terrestrial to aquatic systems and from upper to lower watersheds. However, some actions reduce regional and ecosystem transfers.

a. Increased Sediment Transfers

Actions which remove vegetation disturb the soil, inhibit revegetation, or result in areas which have no vegetative cover, and typically cause erosion and subsequent siltation of local receiving waters. Vegetation helps to maintain soils on a given area through physical impediment of soil particles and movement by roots, stems, and leaves. Vegetation also reduces the energy level of raindrops prior to their striking the ground, which reduces the ability of the rainfall to place soil particles in suspension and thereby remove soil from the site. Vegetation further reduces the quantity of water discharged from a given area, reducing the ability of water to create and move sediments downstream of the site.

TABLE II-XIII. SUMMARY OF WASTE PRODUCTS, TRANSFERS, AND IMPACTS

Wastes	Environments into which Wastes are Discharged/Transferred					Impact	
	Air	Fresh Water	Oceans	Land	Clinical Effects of Residues on Humans?	Fauna	Flora
Gases and associated particulate matter (e.g., SO ₂ , CO ₂ , CO, smoke, soot)	X	T	T	T	Yes	1	1
Photochemical compounds of exhaust gases	X	T	?	T	Yes	1	1
Urban/industrial solid wastes			X	X	No	0	0
Persistent inorganic residues (e.g., lead, mercury)	X	T	T X	X	Yes	2	1
Persistent organic compounds							
Oil			X	T	No	2	1
Organochlorine residues	T	X T	X	X	Disputed	2	1
Pharmaceutical wastes		X	T		Unknown	?	?
Short-life wastes							
Sewage		X	X		Possible pathogen carrier	2	1
Fertilizer residues with N ₂ , P		T	T	X	Yes, especially N ₂	2*	1*
Detergent with P		X	T		No	2*	1*
Radioactivity	X	T	X	T	Yes	2	2
Land dereliction				X	No	2	2
Heat	X	X			No	2*	2*
Noise	X				Yes	1	0
Deliberate wasting — CBW (e.g., defoliation)		T	T	X	Yes	2	2

Key: X — Environments into which wastes are discharged
 T — Environments into which wastes get transferred

0 — Little or no impact
 1 — Moderate impact
 2 — Severe impact

* Aquatic systems

Source: Simmons, 1974, p. 278

Vegetation and erosion must be given special consideration in permafrost areas. Vegetation is a regulatory mechanism in the thermal budget of permafrost areas. Removal of vegetation in permafrost areas can result in increased depth of the active layer, subsidence, surface mass wasting hazards, and less spectacular (though equally severe) erosional gullies. Mass wasting and gully erosion increase sediment transfer from terrestrial to aquatic ecosystems and, if extensive, can increase downstream sediment transfers between regions. Increased imperviousness of a watershed or a segment of a watershed can result in increased water peaks and quantities of discharge, which results in the increased ability of the water downstream of the area to erode and move materials.

b. Decreased Sediment Transfers

Although development actions typically increase the potential for transfers of sediment between environments and regions, some actions reduce transfers (e.g., dredging and damming). Dams act as sediment catchment basins in rivers and reduce the transfer of sediment downstream. Reduction in sediment input to coastal marine beaches may increase beach erosion. In many cases, the damming of rivers has resulted in increased development activity in the upper watershed, which can drastically increase the sediment and material load of the river. This drastic increase can subsequently cause a very rapid and unpredicted deposition of sediment in the dam reservoir. Dredging across areas of littoral drift results in removal of input material downdrift from the dredging site. The frequent result of such an action is erosion of valuable beaches downdrift of the dredged channel.

5. Water Transfers

The effects of development on transfers within the hydrologic cycle are of three basic types: increased transfer rates, decreased transfer rates, and alteration of the temporal pattern of transfer rates.

a. Increased Transfer Rates

Actions which compact soil, remove vegetation, or cover soils with impervious material may result in a decrease in the ability of the watershed to contain water (retention). When this occurs the discharge rates increase. Water is typically discharged shortly following precipitation. Increases in the rate of discharge can cause flooding downstream, scouring, xerification of the watershed, reduction in the recharge of groundwater, increased transfer of sediment and nutrients to systems downstream, and decreased evapotranspiration.

b. Decreased Transfer Rates

Actions which impede or reduce water transfer include damming and removal for human consumption and use. These activities may typically result in the

reduction of normal water transfers out of the watershed. Such actions result in increased evapotranspiration and the raising of groundwater tables. Possible consequences include reduced water availability downstream, waterlogging of soils, and increased concentrations of salts in surface layers of the soil which would normally be removed by leaching. In areas of permafrost, actions which impede runoff can cause permafrost melt, which causes subsidence followed by lake or pond formation.

c. Alteration of Transfer Rates

Not only do development actions change the rates of water transfers between ecosystems and even regions, but they alter the temporal patterns of transfer. Actions that compact soil, remove vegetation, or increase the imperviousness of the watershed generally result in increased fluctuation of flow with higher peaks and lower lows. In such cases removal of water from the watershed quickly follows rainfall or snowmelt. However, when such things as damming occur in conjunction with flood control or consumptive uses, this pattern of removal is often altered. High flows are lowered by closing the spillway and low flows are increased by opening the spillway. Seasonal cycles in water transfers are subsequently muted. Downstream ecosystems which are linked to the normal seasonal fluctuation in water conditions can be strongly affected by such alterations in temporal patterns.

6. Migration

Migratory populations are particularly sensitive to development. Characteristic influences are described in the subsequent paragraphs.

a. Impediments to Migration

Physical impediments to migration by dams, roads, and other rights-of-way can prevent or reduce access to essential habitats of migratory species. Resultant population losses of regional and even national significance are possible. Anadromous fish and caribou are organisms most sensitive to this type of impact, although altitudinal migratory species (e.g., brown/grizzly bears and moose) can also be affected.

b. Infringement on Critical Concentration Areas

Developmental infringement, through habitat alteration, pollution, and disturbance at critical concentration areas (e.g., staging areas, calving areas, wintering grounds, overwintering fishery areas), can have significant deleterious effects on interregional and intraregional populations. Modification of the habitat by vegetation removal, altering succession or changing community composition, can result in less favorable conditions for species using critical areas. Disturbance from noise, human presence, and

domestic pets in these areas can result in reduced reproductive success in some species, increased mortality in other species, and may have no effect in other cases. Introduction of pollutants (particularly in aquatic environments in the form of toxic substances), changes in the levels of dissolved gases, or the introduction of organic materials requiring oxygen for decomposition may result in reduced reproductive success and/or increased mortality, or the aberration of migratory behavior.

c. Selective Pressure on Migratory Behavior

Hunting pressure can establish "artificial" selection on migratory populations by removing individuals traveling through accessible areas during migration. This type of selection can eliminate, reduce, or alter migration patterns, with potential consequences of reduced carrying capacity, overgrazing, erosion, and population collapse.

SECTION III

OCCURRENCE OF SELECTED ACTIONS

In order to identify those areas where the presence of certain natural resources would contribute to their likely exploitation or development, a constraint analysis was made. This analysis identifies the potential occurrence of an activity, but not the expected time of occurrence. The purpose of the analysis is to identify those physiographic units which might be subject to the impacts of certain human activities and the associated environmental features of those physiographic units. The selected regions and physiographic provinces which were evaluated are listed in Table III-1 and shown in Figure 3-1. A description of the key physical and biological processes which distinguish the environment of each of the physiographic units within the 14 analysis regions is contained in the report entitled *The Environment of Alaska: Analysis of Physical and Biological Determinants* (John Graham Company and Boeing Computer Services, Inc., 1976a).

The presence and quantification of the resources subject to development pressure in each physiographic province were determined in *The Environment of Alaska: Resource Specific Quantification* (John Graham Company and Boeing Computer Services, Inc., 1976b). The resources quantified by land units in this document are as follows:

- Renewable Resources

- Agriculture (R_1)
- Range (R_2)
- Forestry (R_3)
- Wildlife (R_4)
- Fisheries (R_5)
- Water (R_6)
- Vegetation types (R_7)
- Recreation opportunities (R_8)
- Preservation opportunities (R_9)
- Subsistence opportunities (R_{10})
- Hydropower opportunities (R_{11})

- Nonrenewable Resources

- Oil and gas (R_{12})

TABLE III-I. SELECTED REGIONS AND MAJOR PHYSIOGRAPHIC UNITS

<u>Region</u>	<u>Major Physiographic Units</u>
A. Arctic	CL, CU, SM
B. Northwest	CL, CU, IL, IU, SM
C. Upper Yukon/Porcupine	IL, IU, SM
D. Tanana	IL, IU, SM
E. Yukon/Koyukuk	IL, IU, SM
F. Yukon/Kuskokwim Delta	CL, CU, SM
G. Upper Kuskokwim	IL, IU, SM
H. Cook Inlet	CL, CU, IL, IU, SM
I. Copper River	IL, IU, SM
J. Aleutian	CL, CU, SM
K. Bristol Bay	CL, CU, SM
L. Kodiak/Shelikof	CU, SM
M. Gulf of Alaska	SM, CL, CU
N. Southeast Alaska	CL, CU, SM

Key: CL — Coastal Lowlands
 CU — Coastal Uplands
 IL — Interior Lowlands
 IU — Interior Uplands
 SM — Steep Mountains *

* Several steep mountain units are not mapped separately from upland units because of size or other reasons.

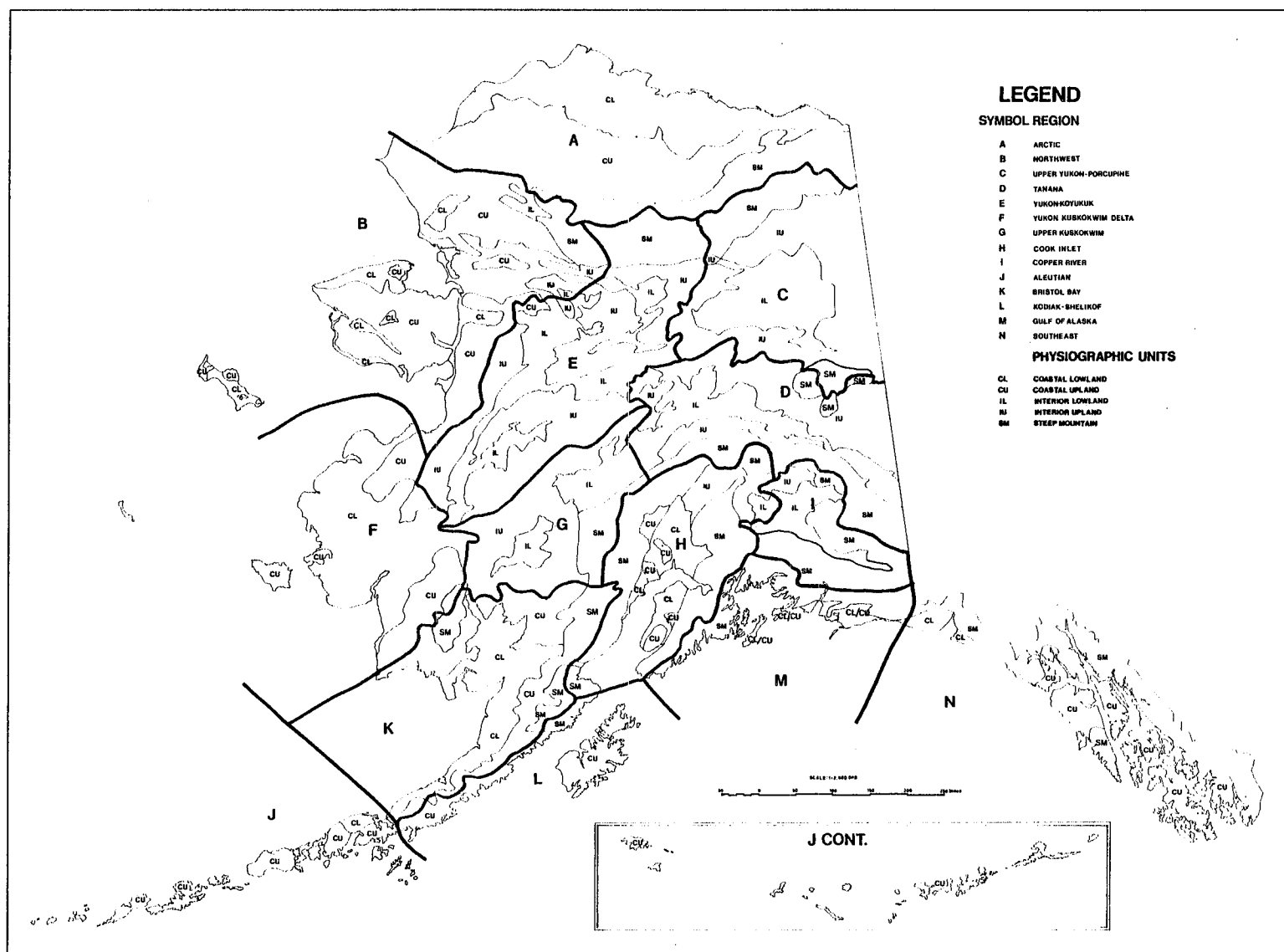


Figure 3-1. Fourteen Analysis Regions of Alaska

APPROXIMATE LOCATION

Coal (R₁₃)
Geothermal (R₁₄)
Mineral extractives (R₁₅)
Areas suitable for urban development (R₁₆)
Antiquities (R₁₇)

The actions which were selected for analysis included all of the Level II (combinations of engineering actions) and Level III (aggregate actions) activities. The basic engineering actions (Level I) were generally excluded from this analysis as they would be expected to generally occur in conjunction with the more complex development activities. Exceptions to this exclusion included the Level I actions of water drilling and dredging. Descriptions of the methods used in each level of analysis are contained in the following subsections.

The basic purpose of this report is to describe the environmental impacts associated with development. In order to determine these impacts, resource development or exploitation was defined as (1) an increase in existing exploitation, or (2) the development of available resources. Based on the development actions selected for this impact analysis, the major resources which would potentially be required include minerals, timber, agricultural lands, fisheries, oil and gas, hydroelectric power, and recreation amenities. The potential occurrence of development actions was therefore determined based on the following criteria:

- Existence and quality of the resource
- Accessibility of the resource
- Development of nearby resources
- Anticipated requirements or existing plans for resource use

Some or all of these factors, depending upon the specific resource, were then considered in order to determine the possibility of the occurrence of various actions within a given physiographic unit. The criteria applied to each selected action are discussed individually and summarized in a table of their potential occurrence by physiographic unit.

A. LEVEL I ACTIONS (by alphabetical designation)

Dredging (F)

The Bureau of Land Management identified areas for water transportation and dock facilities in their preliminary transportation and utility corridor system (1974). Both the Corps of Engineers (Orson Smith, personal communications) and the Division of Waters and Harbors (Alaska State Department of Public Works, Don Stater, personal communications)

identified sites requiring maintenance dredging of existing navigation channels. These sites form the basis of the potential occurrence of the activity.

Potential Occurrence	Criteria Description
0	No identified dredging sites
1	Potential dredging activity for navigation and drainage improvements
2	Maintenance dredging and new dredging activities

B. LEVEL II ACTIONS (by alphabetical designation)

Exploration for Gas and Oil (H)

The potential occurrence of exploration for oil and gas is based on the potential for development of these resources (Federal—State Land Use Planning Commission, 1974).

Potential Occurrence	Criteria Description
0	No potential
1	Oil and gas reserves are assumed to exist based on available geologic data
2	Drilling occurs or has occurred with remaining resources

Road Construction (I)

The Bureau of Land Management (1974) has identified transportation and utility corridors. This identification is based on anticipated needs for development of Alaska's mineral, coal, gas, and oil resources; general transportation; and electrical transmission lines — each requiring the construction of roadways for a particular use. The potential occurrence of roadway construction is, therefore, based on the preliminary conceptual corridor system (Bureau of Land Management, 1974) and the five-year construction program of the Alaska State Department of Highways (1975).

Potential Occurrence	Criteria Description
0	No roadways identified
1	Roadways identified by the corridor system (Bureau of Land Management, 1974)
2	Five-year construction program (State of Alaska, Department of Highways, 1975)

Dam Construction (J)

In this report, it is assumed that all damming activities will be of a multipurpose nature (flood control, power generation, water supply, etc.). Therefore, the potential occurrence of damming is based on the Technical Advisory Committee report on *Resources and Electric Power Generation*, Alaska Power Administration (1974).

Potential Occurrence	Criteria Description
0	No identified sites
1	Sites favorable for potential hydroelectric facilities (61 sites)
2	Projects which appear to have the greatest likelihood of near-future development and the greatest potential in terms of long-range state and national needs (15 sites)

Exploration and Recovery of Hard Rock Minerals (K)

The potential occurrence of activities associated with exploration and recovery of hard rock minerals is based on the potential for development of coal and mineral resources identified by the Federal-State Land Use Planning Commission (1974). The data base is contained in *The Environment of Alaska: Resource Specific Quantification* (John Graham Company and Boeing Computer Services, Inc., 1976b).

Potential Occurrence	Criteria Description
0	No minable resources identified
1	Mineral or coal deposits which are known to occur or which have favorable geological, geophysical, and geochemical data
2	Mineral or coal resource areas which exhibit current mining operations or past producing areas with known remaining resources

Commercial Logging (L)

The potential occurrence of commercial logging in a region was based on the presence of the commercial forest types in the region, as described in *The Environment of Alaska: Resource Specific Quantification* (John Graham Company and Boeing Computer Services, Inc., 1976b), the occurrence of current cutting activities, and the occurrence of population centers.

Potential Occurrence	Criteria Description
0	One percent or less of the resource potential occurs in the region
1	Greater than 1 percent of the state's forest resources occur in the region, but no significant lumber activity or population centers occur in the region
2	Greater than 1 percent of the potential forest resources occur in the area and current logging or population centers occur

Agriculture (M)

Areas in Alaska with agricultural potential have been mapped and published by Reiger (1974), Snodgrass (1974), and the Federal-State Land Use Planning Commission (1974). All maps were based on the Exploratory Soil Survey of Alaska, initiated in 1967 and completed in 1973, at 1:500,000 (by the Soil Conservation Service). Areas with current agricultural use are also identified by Snodgrass (1974) and the Alaska Crop and Livestock Reporting Service (1975). These data are contained in *The Environment of Alaska:*

Resource Specific Quantification (John Graham Company and Boeing Computer Services, Inc., 1976b). The data base was used to determine potential occurrence for development of agriculture resources as follows.

Potential Occurrence	Criteria Description
0	One percent or less of the state's arable lands occur in the area
1	Area has greater than 1 percent of the state's arable lands, but no current agricultural activity and no local markets (population centers)
2	Area has greater than 1 percent of the state's arable lands, has current agricultural utilization and/or local markets (population centers)

C. LEVEL III ACTIONS (by alphabetical designation)

Community Development (N)

The Water Resources Council, Alaska Water Study Committee, has identified regions in Alaska where population increases are expected to cause expansion or growth of existing community settlements (1975). These population increases will result from development of oil and gas resources, mining, tourism, transportation centers, services, and government installations. Therefore, the potential occurrence of new settlements or the growth of existing communities is based on the development of oil and gas, coal, and mineral resources. The data base is derived from those resources identified as having a high potential for development (John Graham Company and Boeing Computer Services, Inc., 1976b).

Potential Occurrence	Criteria Description
0	No resource development
1	New settlements or growth of existing communities from the development of one resource
2	New settlements or growth of existing communities from the development of two or more resources

Recreational Development (O)

The Federal—State Land Use Planning Commission has identified areas in Alaska where recreational activities are expected to be developed. At a minimum, each development facility is expected to provide access facilities for aircraft, passenger boats, motor vehicles, or a combination of each. The areas served may be utilized for intensive recreation, low-density recreation, or wilderness. (Areas intended for intensive recreation generate high activity or participation levels; lower participation levels and recreation pursuits of a passive nature are associated with low-density recreation areas.) Native corporations and federal and state agencies, as well as other private groups, are expected to provide the land and funding for developments. It is assumed that expected developments will occur first at or near major population centers, then along existing or new roads, and finally in bush locations. The level of development will depend on the recreational activity being provided and the demand for that activity. Therefore, the potential occurrence of recreational development is based on the identified focal points.

Potential Occurrence	Criteria Description
0	No resource development proposed
1	Areas in which recreational development has been proposed
2	Areas in which recreational development has been proposed and which are located within 200 air miles of major population and transportation centers

Natural Resource Development Complex (P)

Resource extraction complexes are built for development of oil and gas resources, minerals, coal, fisheries, and timber. Therefore, the potential occurrence of a resource extraction complex is based on the potential for development of these resources, identified by the Federal—State Land Use Planning Commission (1974). The data base is contained in *The Environment of Alaska: Resource Specific Quantification* (John Graham Company and Boeing Computer Services, Inc., 1976b).

Potential Occurrence	Criteria Description
0	No resource development

Potential Occurrence	Criteria Description
1	Resource extraction complex from the development of one resource: oil and gas (HP), minerals (VHP), coal, fisheries, timber
2	Resource extraction complex from the development of two or more resources: oil and gas (HP), minerals (VHP), coal, fisheries, timber

The results of the potential occurrence analyses are shown in Table III-II by region and physiographic province. The mean for each physiographic province provides an indication of which land units have the highest or lowest potential occurrence of the ten human development activities evaluated. Nine physiographic units have a mean expected occurrence value of 0.1 to 0.5, ten units have a mean potential occurrence of 0.6 to 0.9, seventeen units a mean of 1 to 1.5, and five units a mean of 1.6 to 2. In addition, the areas designated follow an expected pattern, with coastal lowland areas having an average expected occurrence of 1.3, coastal uplands 1.14, interior lowlands 0.94, interior uplands 0.87, and steep mountains 0.83.

TABLE III-II. POTENTIAL OCCURRENCE OF SELECTED HUMAN DEVELOPMENT ACTIONS

Regions Physiographic Unit			Level III			Level II						Level I							Mean Ratio for Ten Actions
			P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A	
A. Arctic	CL	1	2	1	2	0	0	2	0	1	2		0						1.0
	CU	2	2	1	2	0	0	2	0	1	2		0						1.0
	SM	3	0	1	0	0	0	1	0	1	1		0						0.4
B. Northwest	CL	4	2	1	2	0	1	2	1	2	2		2						1.5
	CU	5	2	1	2	0	0	2	2	1	1		0						1.1
	IL	6	0	0	0	0	0	2	0	1	1		0						0.4
	IU	7	1	1	1	0	0	2	0	1	0		0						0.6
	SM	8	0	0	0	0	0	1	0	1	1		0						0.3
C. Upper Yukon/ Porcupine	IL	9	2	2	1	1	1	1	2	2	2		1						1.5
	IU	10	2	2	2	1	1	2	2	1	2		1						1.6
	SM	11	1	2	1	0	0	2	0	1	1		0						0.8
D. Tanana	IL	12	2	2	1	2	2	2	1	1	0		1						1.4
	IU	13	2	2	2	2	2	2	1	1	0		0						1.4
	SM	14	1	2	1	0	0	2	1	1	0		0						0.8
E. Yukon/Koyukuk	IL	15	1	2	0	1	1	1	2	1	0		1						1.0
	IU	16	2	0	2	1	1	2	0	1	0		0						0.9
	SM	17	1	2	1	0	0	2	0	1	1		0						0.8
F. Yukon/Kuskokwim Delta	CL	18	2	1	2	1	1	1	0	2	2		2						1.4
	CU	19	1	1	1	0	0	2	0	0	0		0						0.5
	SM	20	1	1	1	0	0	2	0	0	0		0						0.5
G. Upper Kuskokwim	IL	21	2	0	1	1	1	2	0	1	0		1						0.9
	IU	22	2	0	1	1	1	2	2	1	0		1						1.1
	SM	23	0	2	0	0	0	1	0	1	0		0						0.4
H. Cook Inlet	CL	24	2	2	1	2	2	1	1	1	2		2						1.6
	CU	25	2	2	2	2	2	2	1	1	2		0						1.6
	IL	26	0	2	0	0	0	0	0	1	0		0						0.3
	IU	27	0	0	0	0	0	1	2	1	0		0						0.4
	SM	28	2	2	2	0	0	2	2	1	2		0						1.3
I. Copper River	IL	29	2	1	2	1	1	2	0	1	1		0						1.1
	IU	30	0	0	0	0	0	0	0	1	0		0						0.1
	SM	31	2	1	2	0	0	2	0	2	0		0						0.9
J. Aleutian	CL	32	2	0	2	0	0	2	0	1	2		0						0.9
	CU	33	2	0	2	0	0	2	0	1	2		0						0.9
	SM	34	2	0	2	0	0	2	0	1	2		0						0.9
K. Bristol Bay	CL	35	2	1	2	1	1	2	1	2	2		2						1.6
	CU	36	2	2	2	1	0	2	1	1	2		0						1.3
	SM	37	0	2	0	0	0	1	1	1	0		0						0.5
L. Kodiak/Shelikof	CU	38	2	1	2	0	2	2	0	2	2		2						1.5
	SM	39	1	1	1	0	0	2	0	0	1		0						0.6
M. Gulf of Alaska	CL/U	40	2	2	2	0	1	2	0	2	2		2						1.5
	SM	41	2	2	2	0	1	2	2	2	2		0						1.5
N. Southeast	CL	42	1	2	1	0	2	0	0	1	2		2						1.1
	CU	43	2	2	1	0	2	2	1	2	0		0						1.2
	SM	44	2	2	2	0	2	2	2	1	2		0						1.5

Key to Actions: A — Clearing and Grubbing

B — Excavation

C — Construction Filling on Land

D — Foundation Construction

E — Construction Filling in Water and Wetlands

F — Dredging

G — Drilling for Water

H — Exploration for Oil and Gas

I — Road Construction

J — Dam Construction

K — Exploration and Recovery of Hard Rock Minerals

L — Commercial Logging

M — Agriculture

N — Community Development

O — Recreational Development

P — Natural Resource Development Complex

SECTION IV

IMPACT ANALYSIS OF SELECTED HUMAN DEVELOPMENT ACTIONS

One of the major purposes of an impact analysis is to assure that environmental values receive equal consideration with economics in the decision-making process. A principal means to accomplish these objectives is to call attention to environmental relationships which may not have been given adequate consideration during initial planning of a project. The vehicle often employed for such comment and analysis is the environmental impact statement (EIS). The use of such a tool is proving to be an effective and reasonable way to curb pollution and disruption of our environment by placing values on the environment.

The preparation of impact statements by federal agencies was mandated by Congress with passage of the National Environmental Policy Act of 1969 (Public Law 91-190). Since that time, many states and municipalities have adopted similar acts to cover nongovernmental activities. The typical impact statement generally follows the format established by the Council on Environmental Quality (CEQ) and includes the following sections:

- Description of the proposed action
- Description of existing environment
- Environmental impacts of the proposed action
- Unavoidable adverse environmental effects
- Alternatives to the proposed action
- Relationship between local short-term environmental uses and the maintenance and enhancement of long-term productivity
- Any irreversible and irretrievable resource commitments associated with the proposed action

The content of the environmental impact statement transcends those items typically involved in the decision to proceed with a project and requires the knowledge and expertise

of a wide range of environmental scientists, planners, social scientists, economists, and engineers. This interdisciplinary approach to project analysis is designed to examine the consequences of human actions on the natural, physical, and human environments; to determine if the resulting changes will result in significant loss or disruption to the environment; and to provide a discussion of alternatives which will result in less disruption and damage.

In support of this approach, impact analyses have been developed for 17 development actions. The selection of these actions was based on their degree of complexity and potential occurrence within the state of Alaska. The degree of complexity relates to such things as the time required to carry out the action, the level of disruption expected, the amount and extent of resources committed, and the level of activity generated by construction and operation of the project.

Level I actions are defined as basic engineering activities. The actions are generally associated with all development activities, are accomplished within a relatively short time span, often have only short-term impacts on the environment (though these may be significant and severe), and require relatively small commitments of resources and initially high levels of human construction activity. Classifying the severity of an engineering action is subjective at best and frequently is considered a function of the density and distribution of the natural resource (environmental attribute) or the extent of the engineering action. For example, detrimental effects on 10 of 50 localized animals (or plants or other environmental attribute) may be considered severe, whereas impacts on 10 of 5000 animals (or plants or other environmental attribute) may be considered slight. Likewise, construction impacts from one building may be considered slight, whereas impacts from 1000 may be severe. However, in both cases the impact to the animal (or plants or other environmental attributes) is severe in that the animal (plant and/or resource) is exterminated or removed and the completion of the action results in an irretrievable and irreversible condition. Hence, construction and foundations (i.e., Level I activity) is classified as a severe impact regardless of animal population and project size characteristics, and it is only the extent of the impact that changes with the level of action (Level I action versus Level III).

In and of themselves, basic engineering actions are generally not the sole subject of an environmental impact statement. However, they do represent the initial activities undertaken in support of more complex developments which generally require a further commitment of land resources and a commitment over time to an environment dominated by human presence and activity. These Level I actions selected for analysis include

- Clearing and grubbing
- Excavation
- Construction filling on land
- Foundation construction

- Construction fill on water and wetlands
- Dredging
- Drilling for water

Level II actions are combinations of engineering actions which result in the construction of generally single-purpose facilities or activities which are used over an extended period of time. Many of these types of activities have been subjected to the impact statement process. The land and resources committed to support such projects are often extensive. Because of these commitments, the impacts tend to be more extensive and are often felt at distances far removed from the actual project site. For example, road construction requires an extensive commitment of land.

The primary impacts include removal of vegetation and alteration of soils and topography. The indirect impacts associated with use of the road include loss of wildlife habitat; accelerated runoff; contamination of runoff waters from oil, gas, and heavy metals; increased carbon monoxide emissions; and increased noise levels. These impacts in turn create other impacts such as a loss of wildlife carrying capacity, impediments to migration, transport of toxic substances to water bodies (thus adversely affecting fisheries or other aquatic flora and fauna), as well as adverse effects on the health and welfare of nearby residents (human and animal) due to the degradation of the air quality and increased noise disturbances.

In addition to these primary impacts, roads may create an impetus which results in significant secondary effects. Roads open areas to further development, provide access to previously unused areas, and generally stimulate growth. This growth and/or commitment of areas to human use may result in the alteration of an entire area and all the associated natural and physical processes.

For these far-reaching actions, knowledge of the potential changes (short-term, long-term, primary, and secondary) should be examined prior to undertaking a project. A complete analysis of the anticipated changes will allow the project sponsor, land manager, public, and decision-makers to view the project in light of the potential losses accrued and make an informed judgement on whether such losses are outweighed by the gains achieved. The Level II actions selected for analysis include

- Exploration for oil and gas
- Road construction
- Dam construction
- Exploration and recovery of hard rock minerals
- Commercial logging
- Agriculture

Level III actions are termed cumulative based on the fact that they generally involve a variety of human activities and actions and a greater degree of activity. These actions, like those of Level II, are often subjected to the impact statement process. The pollution potential is aggravated by the presence of significant human populations requiring various modes of transportation, public services, utilities, and significantly greater commitments of land and resources over time. As was the case with the Level II actions, these activities may create secondary impacts of greater proportion than those associated with the initial action. In other words, Level III actions are often growth-inducing and attract developments in support of the major activity. Included in this level of action are the following developments:

- Community development
- Recreational development
- Natural resource development complex

The following impact sections contain an analysis of the major environmental effects associated with each action. In order to permit a better understanding of the activities associated with a specific action, a brief descriptive introduction is provided. Following the introduction are discussions of the resources required to carry out the action, some of the permits or regulations which might be required, the activities and equipment employed, and finally the impacts created by the action. These impacts as they affect air quality, noise, water resources, aquatic biology, terrestrial biology, soils, and interactive processes are related to the activities previously described and are not site specific. The relative degree of impact or the severity of the resulting changes to the environment are analyzed by employing a matrix.

For each action the matrix covers each of the state's 44 physiographic units which were previously identified and described in the document entitled *The Environment of Alaska: Analysis of Physical and Biological Determinants* (John Graham Company, 1976). (Also see Table III-I and Figure 3-1 for a graphic view of these units.) These physiographic unit descriptions serve as the basis for the analysis of the severity of the associated impacts. In addition to the severity of impact, the actions are evaluated on the basis of the potential occurrence as described in Section III. Together, these matrixes should assist land use planning in the state of Alaska by providing a basis for determination as to the amount and extent of various impacts as they are related to a wide variety of future development actions.

Finally, it should be kept in mind that a complete and detailed evaluation of impacts from human development activities requires a further site specific level of analysis. Those impacts discussed will provide the land manager and decision-maker with the basic information required to determine how a project might alter the environment. However, in order to fully understand the benefits and losses of any proposal, it will also require detailed

site studies, further analysis of the project components, modeling of all related impacts, discussion of measures which will lessen the severity of various impacts, and a thorough analysis of alternatives which might achieve the project objectives using different methods, other sites, or modified plans.

It should also be kept in mind that impacts vary, not only with geographic location, but also with season and in some cases even with the time of day. Where possible, these variations have been discussed. Due to the number of permutations which could occur, the following impacts generally reflect worst-case conditions with no particular mitigation employed to lessen severity.

A. CLEARING AND GRUBBING

1. Introduction

Land clearing involves the removal of obstructions from the ground surface, and grubbing is the uprooting of stumps, roots, and other obstructions which interfere with subsequent construction. These actions generally precede most other construction activities. Clearing does not involve the demolition or removal of buildings or other human structures. A specific example of clearing and grubbing activity is the preparation of land for house and access road construction.

2. Resources Required to Complete Action

No additional resources beyond equipment, fuel, and manpower are required for clearing and grubbing activities.

3. Permits and Regulations

Clearing and grubbing activities are generally not controlled by permit from a government agency; however, they are often related to the placement of foundations, which may be subject to permit. Burning permits are generally required for associated disposal of refuse from this action.

4. Description of Action and Equipment

Clearing and grubbing involves the removal of aboveground vegetation and subsurface roots and stumps. Generally, small trees and those of no economic value are pushed down with a bulldozer without cutting through the trunk. Larger trees are cut above the ground and the stumps are excavated with a bulldozer. To avoid disturbing adjacent property, hand-clearing and grubbing (in which trees are selectively removed and stumps are

cut flush to the ground) may be required. Chain saws are occasionally used to clear trees in a permafrost area and the ground is disturbed as little as possible to maintain the insulating properties of the groundcover.

Grubbing involves the removal of root systems from the soil so they will not interfere with later construction. In Alaska, root systems are not well developed or extensive enough to require excavation and the roots are usually exposed when the tree is pushed over. Occasionally, large deeply rooted trees are pushed over and excavated with a backhoe or bulldozer to weaken the root system for removal. Equipment similar to that listed for excavation activities (Section IV.B) may be used for clearing and grubbing, depending upon the extent of the activity.

Depending on its value, timber debris may be sold as lumber, removed to an off-site disposal area, or burned. In the majority of cases in Alaska, the last method may be the cheapest, but can have detrimental effects from smoke, fire hazard, and other pollution problems. Burning the debris of a large area requires a permit from the state forester. Commercial logging is uncommon for small projects because of small profit, unmerchantable, and often undesirable wood. Off-site disposal requires a special stockpiling area, which may create a fire hazard. Chipping for mulch is a recent and rather expensive development, but saves the cost of hauling. Oversized wood is sometimes cut for firewood.

5. Impacts

a. Air Quality

A major source of emissions to the atmosphere results from dust generated by activities on the site. Particulate emissions are directly proportional to the area of land being worked, the level of activity, the silt content of the soil, and inversely proportional to the square of the moisture content. Since the burning of refuse is common, the emissions from this practice are also important. Ground level open burning is affected by many variables including wind, ambient temperature, and composition and moisture content of the debris burned; size and shape of the debris; and compactness of the pile. In general, the relatively low temperatures associated with open burning increase the emission of particulates, carbon monoxide, and hydrocarbons, and suppress the emission of nitrogen oxides. Typical values are given in Table IV-I. Mitigating measures such as chipping or use of forced air to achieve cleaner burning can reduce such problems.

b. Noise

During clearing and grubbing, the noisiest sources of equipment at a site are generally trucks (91 dBA) and scrapers (88 dBA). Ground clearing tends to be one of the noisiest phases of construction. Typical composite noise levels for various types of projects are shown in Table IV-II.

TABLE IV-I. EMISSION FACTORS FOR OPEN BURNING
(in pounds per ton)

Pollutant	Agricultural Field Burning	Wood Refuse	Landscape Refuse and Pruning
Particulates	17	17	17
Sulfur oxides	neg	neg	neg
Carbon monoxide	100	50	60
Hydrocarbons (CH ₄)	20	4	20
Nitrogen oxides	2	2	2

TABLE IV-II. TYPICAL NOISE LEVELS DURING
CLEARING AND GRUBBING AT VARIOUS PROJECT SITES

Type of Project	Energy Level, dB(A) *	
	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site
Domestic housing	84	83
Office buildings, hotels, hospitals, and schools	84	84
Industrial parking garage, recreation sites, stores, and service stations	84	87
Public works, roads, highways, sewers, and trenches	84	84

* 50 dBA ambient

Source: Bolt, Barenek, and Newman, 1971a

c. Water Resources

The area cleared and grubbed presents a surface potentially erodible by precipitation and stormwater runoff. The placement of material into suspension depends upon the character of the soil, the topographic gradient, and the amount and type of precipitation. An increase over natural concentrations of suspended matter could result in the impacts identified in Section II.C.1, Turbidity. In larger clearing and grubbing actions, a change in water table can occur and increased flood potentials may also result.

d. Terrestrial Biology

Clearing and grubbing will eliminate endemic plant and resident animal species, likely drive mobile animals away during the activity period, and/or result in the loss or alteration of the habitat. The effects on wildlife depend upon the bird and animal species present on the site, the season of clearing and grubbing, the location of the activity, and the extent of the operation. Permanent loss of habitat used for food and shelter, resting, breeding, and other life processes will result in displaced birds and animals, who may find suitable unoccupied habitat or will compete with members of their own or other species for available habitat. Increased competition will eventually reduce populations. The actual loss of forage plants, however, can be considered minor in relation to total range now available.

Depending upon the extent of the operation, clearing and grubbing will exhibit some or all of the characteristics that occur when vegetation is removed. (See Section II.D.2, Effects of Vegetation Removal.) Foremost among these influences, however, is the often long-range detrimental effect to the soil which is especially important in soils characterized by permafrost, where the active layer is increased, and in soils on steep slopes where mass wasting, etc., is likely to occur. Grubbing will distribute the organic and inorganic materials and result in soils without any characteristic structure. Further, the porosity and permeability of the soil will be influenced by the compaction that occurs when using large bulldozers and other heavy equipment. Where degradation of the permafrost and erosion does not occur, the compaction by vehicles changes the plant composition. A lichen-dominated community may change to a predominately sedge community (Weeden and Klein, 1971) and, although both types are important to caribou, lichen is the superior and chief winter forage which is often in limited supply, whereas sedges are an important summer food.

Secondary environmental impacts will result from air, water, and land pollution resulting from the clearing and grubbing operation. The extent to which these pollutants will influence plant and animal populations will depend on characteristics of the plants and animals on the site and the equipment used in the operation. The general impacts of these environmental pollutants are described in Section II.D. Localized and high concentrations of air pollutants (specifically, sulfur dioxide exhaust emissions from

construction equipment) have been shown to have detrimental effects on the lichens extensively utilized by caribou. Hydrocarbon from clearing and grubbing equipment also may be locally damaging to sensitive plants. In general, clearing and grubbing will make a large area unattractive and unavailable to many animals (e.g., caribou, wolves, sheep, and goats) and will destroy the vegetation on the site.

e. Aquatic Biology

Clearing and grubbing does not normally affect the aquatic environment. However, activities conducted during rainy weather or without proper erosion control could result in the impacts discussed in Section II.E.1. Vegetation removed from stream shorelines increases insolation and could result in increased temperatures and effects discussed in Section II.E.5.

f. Soils

(1) Erosion — The removal of vegetation increases erosion from a given site because (a) raindrops strike the soil surface with full force, which places soil particles into suspension and facilitates their movement by runoff; (b) rainfall on bare soils can form surface slush that seals soil pores and increases surface runoff; (c) removal of stems and roots of vegetation, which mechanically inhibit the movement of water and soil particles, decreases resistance to surface flow and movement of soil particles; and (d) sunlight and wind acting directly on the soil can accelerate drying of the soil, which results in wind erosion. The erosion potential of soils is largely based on soil type and slope. Increased slope increases the erosion potential for any given soil, while soil particle size and cohesiveness are inversely related to the erosion potential of the soil. Immediate revegetation, careful site drainage, and buffer strips can mitigate these impacts.

(2) Sedimentation — Soil erosion is frequently accompanied by sedimentation. Sediment removed from the site by erosion is deposited off the site, frequently in streams and lakes. Actions taken to mitigate erosion will mitigate sedimentation. In addition, sediment basins can be used to trap sediments before they enter aquatic environments.

(3) Mass Wasting — Removal of vegetation and grubbing can result in increased probability of mass wasting. Of particular sensitivity are areas of steep slopes and high precipitation, areas of permafrost, and areas of porous soils underlain by tilted impervious material. Mass wasting in areas of permafrost is discussed in Section II.F. Removal of vegetation decreases the coefficient of friction for the weathered rock debris (soil) by reducing the anchoring effect of roots. In southeast Alaska, Swanston (1969) states that slopes greater than 34 degrees are highly susceptible to landslides.

(4) Subsidence — Subsidence can occur following clearing and grubbing in areas of permafrost. (Refer to the discussion on permafrost, below.)

(5) Compaction — Clearing and grubbing with heavy equipment, particularly if repeated, can lead to compaction in some soils. Most Alaskan trees are shallow-rooted; therefore, their root systems are susceptible to compaction and are easily damaged.

(6) Permafrost — In areas underlain by permafrost, clearing and grubbing can lead to severe erosion, mass wasting, and subsidence. Removal of vegetation and grubbing disturbs the thermal equilibrium between the permafrost, the active layer, surface vegetation, and climatic conditions. Permafrost areas of fine soils with high ice content are the most sensitive to disturbance because they tend to consolidate considerably upon melting and cannot readily discharge moisture from melted interstitial ice. Subsidence is more apt to occur on level ground, while mass wasting is more typical in steeper areas. However, liquifaction of the active layer, particularly during spring thaw, can move materials through solifluction on slopes of less than 3 degrees. Most erosion and mass wasting will occur during the critical spring thaw period (U.S. Department of the Interior, 1975).

(7) Changes in the Biological, Chemical, and Physical Properties of the Soil pH — In taiga and tundra soils, clearing and grubbing can be expected to change soils from acid to alkaline conditions and have dramatic effects on the biology of the soil by generally changing the decomposer community from one dominated by fungus to one dominated by bacteria (Flannagan, et al, 1970). This results in more rapid decomposition of organic material and an increase in nutrient release. Undeveloped surface mineral soils in southeast Alaska are alkaline (pH = 8), but become slightly acidic (pH = 5) in 30 to 50 years as they mature (Hanes, et al, 1974). Clearing and grubbing may reverse this trend in pH.

(8) Temperature — Clearing and grubbing result in increased average spring, summer, and fall soil temperature, and increased diurnal fluctuation in soil temperatures. Although the effects of vegetation removal have not been measured for many areas in Alaska, increases of 6 degrees F at a 3-inch depth and 5 degrees F at a 24-inch depth have been recorded following clear-cutting in southeast Alaska (Gregory, 1956). In areas of permafrost, removal of vegetation and organic surface mat reduces insulation and shading. Consequently, soil temperature increases are followed by degradation of permafrost and increase in the depth of the active layer.

(9) Nutrients — Losses of soil from the site caused by erosion include losses of nutrients within the body of the soil. Likewise, the removal of plant material from the site will result in a loss of the nutrient capital of the site. Increased soil temperature caused by removal of vegetation establishes greater soil decomposer activity, with subsequent

increased nutrient release from organic materials of the soil. If revegetation occurs immediately, a portion of these released nutrients are taken up by the invading plant. If revegetation does not occur, leaching can result and a transfer of nutrients to aquatic systems is probable, which increases the need for artificial refertilization of the soils.

(10) Soil Structure — Clearing and grubbing through compaction agitation, shearing, and losses of divalent bonding agents can cause a breakdown of soil body. Soils of southeast Alaska are particularly sensitive to degradation of soil body (Harris, et al, 1974). In addition, soil zonal layers will be disturbed and liquid water volume, water vapor volume, soil air volume, and soil community composition will be altered.

g. Interactions

Potential consequences of clearing and grubbing on interactions are itemized as follows:

(1) Increased sediment and nutrient transfer from terrestrial to aquatic systems can occur. Potential secondary effects are a reduction in spawning habitat, alteration in makeup of benthic communities, decreased light penetration with possible localized reduction in primary production, and increased nutrient concentrations with subsequent changes in productivity.

(2) Some possibility of accidental spill of toxic substances, particularly petrochemical products, may occur. Through incomplete combustion and engine drip, small quantities can be expected to find their way to aquatic systems. Petroleum contaminants have both immediately lethal and chronically toxic effects on biota. Secondary effects are also deleterious (e.g., interference with gas exchange at water surface and matting of fur or feathers, with subsequent loss in insulation and/or buoyancy).

(3) Without appropriate mitigating measures, clearing and grubbing in areas of permafrost can result in subsidence due to changes in the thermodynamics of the surface heat exchange layer by removal of insulating organic material. The collection of water in depressions, with its high specific heat, further activates thawing of permafrost. Subsidence in permafrost areas frequently results in the formation of water bodies.

(4) In areas of seasonal concentrations, disturbance of migratory species by noise, habitat removal, or presence of humans can have significant adverse effects on regional, statewide, and nationwide populations.

IMPACT ANALYSIS, CLEARING AND GRUBBING

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL			1,2,3,4,5,6	1b 3a,b,d					1	1a 2a,c,j	2i 5a,6	1b,c		1,c,d	1,a,b,c,e	5,6,7 8b,c	2,3 8a	8,d	6,b	2a 4a	2,c	
	CU			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,j	2,c,j	1b,c 6			1	2,3,4,5,6,7 8b,c	8a	8,d	4a	2,a,c	6,b	
	SM			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,j	2i	1b,c 3b,6			1	2,3,4,7 8b	5 8,c	6 8a	4a		2,a,c	
B. NORTHWEST	CL			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,j	6	1b,c 2,c,j,3b			1	5,7 8b,c	2,3 8a	8,d		2a 4a,5b	2,c	
	CU			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,j	2i	1b,c 6			1	2,3,4,7 8b,c	5 8a	8,d	4a	2a	2,c 6b	
	IL	1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e,j	1b,c 6			1	7 8b,c	2,3,4,5 8a,b				2,a,c 4a,5a	
	IU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e,j	1b,c 6			1	7 8b,c	2,3,4,5 8a				2,a,c 4a,5a	
	SM			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,j	2i	1b,c 3b,6			1	2,3,4,7 8b	5 8,c	6 8a	4a		2,a,c	
C. UPPER YUKON/ PORCUPINE	IL	1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,j,6	2,d	1b,c 2i			1	5,7 8b,c	8a	2,3 8,d	6,b	2,c	2a 4a,5a	
	IU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,j,6	2,h,d	1b,c 2i			1	2,3,4,7 8b,c	6 8a	8,d	4a	2a 5b	2,c 5a	
	SM			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,d,e,j		1b,c 2i,6			1	2,4	3,5,7	8a,b	4a	2,a,c		
D. TANANA	IL	1 2a,c,d	2b 3	4,5,6	1b 3a,b,d					1,6	1a 2a,j	2,c,d	1b,c 2i,6			1		5 8a,b,c,d	2,3,7		2,c	2a 4a,5a	
	IU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e,h,i	1b,c 2i,6			1		2,3,4,7 8a,b,c	5 8,d		2,c 4a,5b	2a 5a	
	SM			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,d,e,j		1b,c 6			1	2,4	5,7	8a,b	4a	2,c	2a	
E. YUKON/KOYUKUK	IL	1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2i,j	6	1b,c 2,c,d,e,j			1		2,3,5,7 8a,b,c	8,d		2,c 6b	2a 4a,5a	
	IU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e	1b,c 2i,6			1	2,3	4,7 8a,b,c	5 8,d		2,c 4a	2a 5a	
	SM			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,d,e,j		1b,c 6			1	2,3,4	5,7	8a,b	4a	2,c	2a	
F. YUKON/ KUSKOKWIM DELTA	CL			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2i		1b,c 2,c,d,e,j			1	5,7	2,3 8a,b,c	8,d	6,b	2,c 4a	2a	
	CU			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e	1b,c 2i,6			1	2,3,4,7	5 8a,b,c	8,d		2,c 4a	2a	
	SM			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,d,e,j		1b,c 2i,6			1		2,3	4,5,6 8a,b,c,d		2,a,c 4a		
G. UPPER KUSKOKWIM	IL	1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,j	2,c,d	1b,c 2i,6			1		5 8a,b,c	2,3,7		2,c	2a 4a,5a	
	IU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e,h,i	1b,c 2i,6			1		2,3,4,7 8a,b,c	5 8,d		2,c 4a,5b	2a 5a	
	SM			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,d,e,j		1b,c 6			1	2,3,4	5,7	8a,b	4a	2,c	2a	
H. COOK INLET	CL	1 2a,c,d	2b 3	4,5,6	1b 3a,b,d				1	6	1a 2i	2,c,d,e	1b,c 2i,6		1,d,e	1,a,b,c,f		8a,b,c	2,3,6 8,d		2,c	2a 4a,5a	
	CU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e	1b,c 2i,6			1		2,3,4 8a,b,c	6 8,d		2,c 4a	2a 5a	
	IL	1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e	1b,c 2i,6			1	5,7	2,3,4 8a,b,c	8,d		2,c 4a	2a 5a	
	IU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,d,e,j	2,g	1b,c 2i,6			1		2,3,4,7 8a,b,c	6 8,d		2,c 4a	2a 5a	
	SM			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,d,e,j		1b,c 6			1	2,3,4		8a,b,c,d		2,a,c 4a		
I. COPPER RIVER	IL	1		2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,j		1b,c 2,c,d,e,j,6			1	5,7	2,3 8a,b,c	8,d		2,a,c 4a	5a	
	IU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,j	2,c,d,e	1b,c 2i,6			1		2,3,4,7 8a,b,c	6 8,d		2a 4a	2,c 5a	
	SM			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,d,e,j		1b,c 2i,6			1	2,3,4	5,7	8a,b,c,d		2,a,c 4a		
J. ALEUTIAN	CL			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j	2i	1b,c 6			1		2,3,4,5 8a,b,c,d			6,b	2,a,c 4a,5a	
	CU			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 6			1		2	3,6 8a,b,c,d		6,b	2a	2,c 5a
	SM			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,d,e,j		1b,c 2i,6			1	2,3,4		8a,b,c,d		2,a,c 4a		
K. BRISTOL BAY	CL		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i		1b,c 2,c,d,e,j,6		1,d,e	1,a,b,c,f		2,3,5,6 8a,b,c,d		6,b		2,a,c 4a,5a	
	CU			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e	1b,c 2i,6			1		2,3,4	5,6 8a,b,c,d		4a	2,a,c 5a	
	SM			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,d,e,j		1b,c 2i,6			1	2,3,4		8a,b,c,d		2,a,c 4a		
L. KODIAK/SHELIKOF	CU		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e,j	1b,c 6			1		2,3	4,5,6 8a,b,c,d	6,b	4a 5a	2,a,c	
	SM			1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,c,d,e,j		1b,c 2i,6			1	2,3,4		8a,b,c,d		2,a,c 4a		
M. GULF OF ALASKA	CL/ CU		1,2,3	4,5,6	1b 3a,b,d				6	1	1a 2i	2,c,d,e	1b,c 2i,6		1,d,e	1,a,b,c,f	2,3,4	6 8a,b,c	8,d	6,b	2,a,c 4a	5a	
	SM		1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2i	2,c,d,e	1b,c 2i,6			1	2,4	3 8b	8a,c,d	6,b	4a	2,a,c 5a	
N. SOUTHEAST	CL		1,3	2,4,5,6	1b 3a,b,d					1,6	1a 2i		1b,c 2,c,d,e,j,6			1		2,3 8a,b,c,d		6,b	2,c	2a 4a,5a	
	CU		1,2,3	4,5,6	1b 3a,b,d				6	1	1a 2i	2,c,d,e	1b,c 2i,6		1,d,e	1,a,b,c,f	2,3,4	6 8a,b,c		6,b	2,a,c 4a	5a	
	SM			1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,c,d,e,j		1b,c 2i,6			1	2,3,4		8a,b,c,d		2,c 4a	2a	

B. EXCAVATION

1. Introduction

The act of excavation is the digging, scooping, or cutting of material resulting in a hole or change in the original surface condition. For this report, excavated materials include soil, rock, peat, mineral resources, and ice. Excavation is accomplished through processes dependent upon the qualities and quantities of the material to be excavated, the sensitivity of the environment, and economic considerations. Common excavation processes include manual and mechanical digging, drilling and blasting, and hydraulic sluicing.

Common excavation is the removal of materials by mechanical or hydraulic means without the use of explosives, while rock excavation is the removal or disposal of rock larger than 1-1/2 cubic yards or any solid rock requiring blasting for removal. The basic purposes for surface excavation are to

- Remove and relocate surplus material for foundations or to contour roadways and drainages
- Relocate material for use at a different site such as the excavation of gravel from a borrow pit

2. Resources Required to Complete Action

Equipment, fuel, manpower, and land use requirements are project-dependent. A rock quarry, for example, requires land to maneuver trucks, park idle equipment, stockpile material, and store refuse. If processing plants (crushing, screening, etc.) are used, the land requirements increase tremendously for plant construction and material storage.

3. Permits and Regulations

Excavation activities are generally not controlled by permit from a government agency; however, they are often related to the placement of foundations, which are subject to permit in major cities.

4. Description of Action and Equipment

Following clearing and grubbing operations, unsuitable material is removed from the site. The area is then surveyed through cross-sectioning. During this operation, the area to be excavated is sectioned into 25-foot grids to determine the amount of material excavated through comparison of grid point elevations. Construction methods employed in common excavations may involve the equipment listed in Table IV-III.

TABLE IV-III. EQUIPMENT UTILIZED IN EXCAVATION ACTIVITIES

Excavation Equipment

Dipper shovel
Hoe shovel
Dragline
Clamshell
Hydraulic shovel
Drag scraper
Backhoe
Paddler loader
Bucket loader
Crawler tractor
Wheeled tractor
Cabledozer
Hydraulic dozer
Front-end loader

Compacting Equipment

Tandem roller
Towed roller
 Sheepsfoot
 Tamping roller
 Pneumatic-tired (self-powered)
Vibrator compactor

Rough and Fine Grading Equipment

Towed scraper
Self-powered scraper
Leveling-drag scraper
Land leveler
Land plane
Paddle-wheel scraper
Motor grader

Hauling Equipment

Light dump truck
Off-the-road dump truck
Bottom dump truck
Side dump truck

Miscellaneous Equipment

Compressor
Generator
Drill rig
Water truck

Where solid rock is excavated, explosives are detonated within predrilled holes and the material is removed to a disposal site. If the material is loose rock or aggregate, or the soil is cemented, shovel operations are often employed to load trucks for transport to fill sites. During deep excavation, groundwater may be encountered. Dewatering is required, especially in sand and soils where extreme instability may occur at the bottom of the excavation due to excessive shear stress.

Permafrost excavation in Alaska occurs by thawing the soil prior to excavation or by fracturing the frozen soil into removable pieces. Soil may be thawed by solar radiation after the removal of natural insulation such as vegetation. By removing the vegetative mat, the active layer thaws sooner and expands. After thawed material is removed, the remaining soil is then subjected to thawing, thus creating a new active layer which subsequently may be excavated. In placer mining operations, water jets are used to speed thawing and excavate simultaneously.

In many cases, the fracturing method is considered more desirable for permafrost excavation, as it can be less expensive than mechanization and more expedient than either mechanized or solar radiation techniques. In confined areas or on small projects, saws and pneumatic hammers are used. Obviously, this procedure has limited application, although it offers flexibility which larger equipment techniques do not have. Steam drilling is used for small excavations such as setting piling in permafrost soils or thawing small areas. This technique requires precision to prevent the steam from thawing the surrounding areas not intended for excavation.

Permafrost slope cuts are limited to a maximum slope of 2:1, unless otherwise substantiated by a soils investigation. For excavations less than 12 feet deep, the excavator is generally responsible for settling or caving on adjacent property resulting from inadequate precautions or protection. For further detailed information, refer to the Uniform Building Code and local construction specifications (e.g., *Standard Construction Specifications of the Greater Anchorage Area Borough*, 1973). In almost all engineering projects, if unsuitable materials are encountered, they are removed by excavation and replaced with satisfactory materials.

5. Impacts

a. Air Quality

The major source of emissions to the atmosphere results from dust generated by activities on the site. Particulate emissions are directly proportional to the area of land being worked, the level of construction activity, and the silt content of the soil (i.e., particles smaller than 75 μm in diameter) and inversely proportional to the square of the moisture content as represented by Thornthwaite's precipitation/evaporation index. An

approximate emission factor is 1.2 tons per acre of construction per month of activity (U.S. Environmental Protection Agency, 1975).

Stone quarrying and crushing operations result in further emissions, given in Table IV-IV. Factors affecting emissions include the amount of rock processed; the method of transfer of the rock; the moisture content of the raw material; the degree of enclosure of the transferring, processing, and storage areas; and the degree to which control equipment is used on the processes.

Gaseous emissions from diesel-powered vehicles may be estimated from values given in Table IV-V. Since excavation generally occurs after the ground is thawed, formation of ice fog is not expected. The removal of topsoil and the insulating material on the surface will increase the heat balance of the soil surface and may influence the depth of penetration of energy into the soil. Particulates settling on snow surfaces may be sufficient to locally increase the rate of snowmelt.

b. Noise

The major type of internal combustion equipment present during excavation is highly mobile earth-moving equipment. Noise levels at 50 feet from earth-moving equipment range from about 73 to 96 dB(A). Generally this phase of construction is the noisiest. Typical composite noise levels for various types of construction projects during excavation are shown in Table IV-VI.

c. Water Resources

The site of the excavation presents a surface potentially erodible by precipitation and stormwater runoff. Any suspended material not trapped within the excavation or that is suddenly flushed out could change natural concentrations of suspended matter, resulting in the impacts identified in Section II.C.1, Turbidity.

d. Terrestrial Biology

Both primary and secondary effects may be expected from surface excavation. Primary impacts of excavation include the permanent or temporary removal of endemic plant communities. The removal of vegetation will result in some of the outcomes described in Section IV.A.5.f, of which the possibility of increased landslides and rapid water runoff would be the most important. Localized sources of air pollution may occur either from the use of excavation equipment or from the accidental spillage of industrial fuel. One of the most serious influences on plants and animals, especially in the arctic tundra, is the production of particulate matter. (See Section II.D.)

TABLE IV-IV. PARTICULATE EMISSION
FACTORS FOR ROCK-HANDLING PROCESSES

Type of Process	Uncontrolled Total		Suspended Emission	
	lb/ton	kg/MT	lb/ton	kg/MT
Dry crushing operations				
Primary crushing	0.5	0.25	0.1	0.05
Secondary crushing and screening	1.5	0.75	0.6	0.3
Tertiary crushing and screening (if used)	6.0	3.0	3.6	1.8
Recrushing and screening	5.0	2.5	2.5	1.25
Fines mill	6.0	3.0	4.5	2.25
Miscellaneous operations				
Screening, conveying, and handling	2.0	1.0		

Source: U.S. Environmental Protection Agency, 1975

TABLE IV-V. EMISSION FACTORS FOR
HEAVY-DUTY DIESEL-FUELED VEHICLES

	Running (30 kph) (in grams/kilometer)	Idle (in grams/minute)
Carbon monoxide	17.8	0.64
Hydrocarbons	2.9	0.32
Nitrogen oxides	13.0	1.03
	(11.2 for new diesels after 1978)	
Particulates	0.81	
Sulfur oxides	1.7	
Aldehydes	0.2	
Organic acids	0.2	

Source: U.S. Environmental Protection Agency, 1975

**TABLE IV-VI. TYPICAL NOISE LEVELS
DURING EXCAVATION AT VARIOUS PROJECT SITES**

Type of Project	Energy Level, dB(A) *	
	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site
Domestic housing	88	75
Office buildings, hotels, hospitals, and schools	89	79
Industrial parking garage, recreation sites, stores, and service stations	89	71
Public works, roads, highways, sewers, and trenches	88	78

* 50 dBA ambient

Source: Bolt, Beranek, and Newman, 1971a

Wildlife living within or depending upon the plant community that is being removed as a result of excavation may either die or emigrate (which may further decrease their life expectancy), depending on species characteristics, season, habitat type, and terrain. Drilling, use of explosives, power shovels, and other noisy heavy equipment are especially distressing to animals during the breeding season. Birds frequently abandon nests and their young when disturbed, and mammals may fail to breed or successfully nurse and protect their young. In caribou and other ungulates, harassment interferes with the normal interaction of cow and calf and causes the pair to move before the calf is dry or has nursed properly. In extreme cases, cows will abandon calves, which then have little chance of survival. In addition, scattered mature animals exhibit higher mortality rates because they are more vulnerable to predation.

The extensive human activity commonly associated with excavation projects will also negatively influence animal behavior, especially those species that are incompatible with man, such as bear and wolf. Behavioral changes may include social dislocation, as described in Section II.D and the preceding text.

e. Aquatic Biology

Surface excavation does not normally affect the aquatic environment. Extensive excavation may alter drainage to a degree that the receptor stream or water body can be damaged by sediments and increased runoff. Activities conducted during rainstorms or without proper erosion control could result in the impacts discussed in Section II.E.1.

f. Soils

Those impacts discussed in Section IV.A, Clearing and Grubbing, are also applicable to excavation. Additional impacts are as follows:

- Excavation will change the biological, chemical, and physical makeup of the soil.
- Excavation generally disrupts the integrity of the surface soil layer.
- Revegetation on excavated soils must start with primary plant succession. Therefore, an excavated site will take a long time to recover from this impact and again be useful to wildlife or man.

g. Interactions

Potential consequences of excavation on interactions are itemized as follows:

(1) Increased sediment and nutrient transfer from terrestrial to aquatic systems can occur. Potential secondary effects are a reduction in spawning habitat, alteration in makeup of benthic communities, decreased light penetration with possible localized reduction in primary production, and increased nutrient concentrations with subsequent changes in productivity.

(2) Some possibility of accidental spill of toxic substances, particularly petrochemical products, may occur. Through incomplete combustion and engine drip, small quantities can be expected to find their way to aquatic systems. Petroleum contaminants have both immediately lethal and chronically toxic effects on biota. Secondary effects are also deleterious (e.g., interference with gas exchange at the water surface and matting of fur or feathers, with subsequent loss in insulation and/or buoyancy).

(3) Without appropriate mitigating measures, excavation in areas of permafrost can result in subsidence due to changes in the thermodynamics of the surface heat exchange layer by removal of insulating organic material. The collection of water in depressions, with its high specific heat, further activates thawing of permafrost. Subsidence in permafrost areas frequently results in the formation of water bodies.

(4) Blasting associated with rock excavation may be lethal to localized aquatic populations. The extent of lethal range is a function of the size of the charge and the velocity of the shock wave. Slow velocity charges (i.e., black powder) are less lethal. Species sensitivity to blasting varies, those with air bladders being generally more sensitive. Salmon eggs in gravel are highly sensitive to shock waves. State laws prohibit blasting within one quarter of a mile of a salmon spawning stream.

(5) In areas of seasonal concentrations, disturbance of migratory species by noise, habitat removal, or presence of humans, can have significant adverse effects on regional, statewide, and nationwide populations.

IMPACT ANALYSIS, EXCAVATION

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-38 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL				1,2,3,4,5,6	1b 3a,b,d					1	1a 2,c,d,e,j		1b 2i;6		1,a,b,e	5,7 8a,b,c,d	2	3		6b	5c	2a 4a
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	2,3,4,5,7 8a,b,c,d				2c 4a;5c		2a
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	2,3,4 5,7 8a,b,c,d				2a 4a		2c 5c
B. NORTHWEST	CL				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b 2i;6		1	5,7 8a,b,c,d	2	3		6b	5c	2a 4a
	CU				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b 2i;6		1	2,3,4,5,7 8a,b,c,d				2c 4a;5c		2a
	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	8a,b,c,d	5,7	2,3			2a,c 4a;5c	
	IU		1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	2,3,4,5,7 8a,b,c,d				2c 4a;5c		2a
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	2,3,4 5,7 8a,b,c,d				2a 4a		2b 5c
C. UPPER YUKON/ PORCUPINE	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	8a,b,c,d	5,7	2,3	6b	2c	2a 4a;5c	
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	8a,b,c,d	2,3,4,5,7			2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b 2i;6		1	2,3,4 7 8a,b,c,d		5		4a		2a,c 5c
D. TANANA	IL	1 2,a,c,d		2b 3	4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	8a,b,c,d	6	2,3			2a,c 4a;5c	
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	8a,b,c,d	2,3,4,5,7			2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b 2i;6		1	2,3,4 7 8a,b,c,d		5		4a		2a,c 5c
E. YUKON/KOYUKUK	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	5,7 8a,b,c,d	6	2,3			2a,c 4a;5c	
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	4,5 8a,b,c,d	2,3,5,7			2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 8a,b,c,d	7	4		4a		2a,c 5c
F. YUKON/ KUSKOKWIM DELTA	CL				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	5,7 8a,b,c,d	6	2,3	6b		2a,c 4a;5c	
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	4,5,7 8a,b,c,d	2,3,6			2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 8a,b,c,d		5,7		2a,c 4a		5c
G. UPPER KUSKOKWIM	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	8a,b,c,d	6	2,3			2a,c 4a;5c	
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	4 8a,b,c,d	2,3,5,6,7			2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	4 8a,b,c,d	2,3			2c 4a		2a 5c
H. COOK INLET	CL	1 2,a,c,d		2b 3	4,5,6	1b 3a,b,d			1		6	1a 2,c,d,e,j		1b,c 2i;6		1,a,e 1,a,b,c,f	8a,b,c,d	6	2,3			2a,c 4a;5c	
	CU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	8a,b,c,d	2,3,4,6					2a,c 4a;5c
	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	5,7 8a,b,c,d	6	2,3			2a,c 4a;5c	
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	4,5,7 8a,b,c,d	2,3,6			2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1	2,3 8a,b,c,d				2a,c 4a		5c
I. COPPER RIVER	IL	1			2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1	5,7 8a,b,c,d	6	2,3			2a,c 4a;5c	
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	4,5,7 8a,b,c,d	2,3,6			2a,c 4a		5c
	SM				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 7 8a,b,c,d				2a,c 4a		5c
J. ALEUTIAN	CL				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	8a,b,c,d	6	2,3,5			2a,c 4a;5c	
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	8a,b,c,d	6	2,3,4	2c 6b			2a 4a;5c
	SM				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 8a,b,c,d		7			2a,c 4a;5c	
K. BRISTOL BAY	CL			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1,a,e 1,a,b,c,f	8a,b,c,d	6	2,3,5,7			2a,c 4a;5c	
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	8a,b,c,d	2,3,4	5,6		2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 8a,b,c,d		5,7		2a,c 4a		5c
L. KODIAK/SHELIKOF	CU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	8a,b,c,d	2,3,6			2c 4a;5b		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 8a,b,c,d		7			2a,c 4a;5c	
M. GULF OF ALASKA	CL/ CU			1,2,3	4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1,a,e 1,a,b,c,f	2,3,4,6 8a,b,c,d			6b	2c 4a		2a 5c
	SM			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 8a,b,c,d		5		2a 4a		2c 5c
N. SOUTHEAST	CL			1,3	2,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	8a,b,c,d	6	2,3,5			2a,c 4a;5c	
	CU			1,2,3	4,5,6	1b 3a,b,d			6		1	1a 2,c,d,e,j		1b,c 2i;6		1,a,e 1,a,b,c,f	2,3,4,6 8a,b,c,d			6b	2c 4a		2a 5c
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2,c,d,e,j		1b,c 2i;6		1	2,3,4 8a,b,c,d		6		2a,c 4a		5c

C. CONSTRUCTION FILLING ON LAND

1. Introduction

Filling is the process of depositing solid material to fill depressions or build up existing topographic features on land. Fill material may include soil, rock, or solid waste. This discussion will involve the methods and requirements related to landfill employing soil and rock materials. Filling on wetlands is discussed in Section IV.E.

2. Resources Required to Complete Action

Major emphasis on the quality of fill material is placed on the compactibility of the material for support and impermeability. Selected fill material may be composed of specific combinations of soil and rock to utilize the particular properties of the combination.

3. Permits and Regulations

Where fill is required, the type of material is specified in construction documents. The placement of fill, however, is controlled by city, borough, and state agencies. The Alaska Department of Natural Resources has required permits for some filling operations.

4. Description of Action and Equipment

The landfill site is first cleared and grubbed and the topsoil is removed. Undesirable subsurface material is also removed and replaced by frost-resistant granular material. The site is then compacted. The fill material is then spread over the site and compacted in layers to the grade and site lines specified. The machinery requirements are similar to those required for excavation (e.g., hauling, grading, and compacting equipment). (See Table IV-III.) Fuel needs are generally the same as those necessary for excavation.

Backfilling and dumping are typical placement functions, and the fill may be compacted through static weight, kneading action, pneumatic tire, and impact. Backfilling involves the replacement of material in an area that has been previously excavated and then compacted. Most frequently, the material excavated from the site is utilized. Peat can be used in agriculture as an organic fertilizer and to condition the soil, for mulching, and for landscaping.

Static weight compaction is commonly used in fill operations and utilizes the weight of smooth-surfaced rollers to compress the fill. The use of steel-wheeled rollers is generally limited to surficial compaction and coarse aggregates where crushing action is most useful. Kneading compaction employs the use of sheepfoot rollers (steel drums surfaced

with metal projections). The projections (feet) compact the lower layers and, as the feet lift out of the fill, the material remains completely compacted. Pneumatic tire compaction is similar in concept to the preceding method, except that the roller is comprised of numerous tires which knead and compact the fill by their weight and wobbling action. Impact compaction is accomplished with an automated hammer which pounds the fill to compaction. This method is most useful in confined areas which are not accessible to the other machinery discussed.

5. Impacts

a. Air Quality

The major source of emissions to the atmosphere from landfill operations results from the transport and processing of fill materials. Particulates are blown from the loads of dump trucks and road dust is stirred up by the movement of vehicles on the bare surface. Control techniques involve watering, chemical stabilization, and reduction of surface wind speed using windbreaks or source enclosure. The quantity of suspended dust emissions in pounds per ton of fill may be estimated by the following expression:

$$\text{Emissions Factor} = \frac{0.33}{(\text{PE}/100)^2}$$

where

PE = Thornthwaite's precipitation/evaporation index
(U.S. Environmental Protection Agency, 1975)

Gaseous emissions from the vehicles used in the operations may be estimated from values given in Table IV-V.

When temperatures are below minus 30 degrees F, the combustion of fossil fuels will serve to increase the humidity of the air. If there is not sufficient wind to dissipate this water vapor, fog may form that may persist for hours or days. The change in thermal characteristics of the surface layers, depending on the type of fill, will influence the thermal structure in the soil and may modify temperatures at the surface slightly or may serve as an additional insulating layer for permafrost beneath.

b. Noise

Filling, like clearing and grubbing and excavation, requires primarily earth-moving equipment. The associated noise levels at 50 feet range from 73 to 96 dBA

during this phase of construction. Site noise characteristics are similar to those shown in Table IV-VII for various types of construction projects.

TABLE IV-VII. TYPICAL NOISE LEVELS
DURING FILLING AT VARIOUS PROJECT SITES

Type of Project	Energy Level, dB(A)*	
	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site
Domestic housing	83	83
Office buildings, hotels, hospitals, and schools	84	84
Industrial parking garages, recreation sites, stores, and service stations	84	83
Public works, roads, highways, sewers, and trenches	84	84

* 50 dBA ambient

Source: Bolt, Beranek, and Newman, 1971a

c. Water Resources

The area filled presents a surface potentially erodible by precipitation and stormwater runoff. The placement of material into suspension depends upon the character of the fill and the amount and type of precipitation. An increase over natural concentrations of suspended matter could result in the impacts identified in Section II.C.1, Turbidity.

d. Terrestrial Biology

Landfilling operations directly and indirectly influence plants and animals. The area of average depth of fill and season of operation will to a large extent determine the specific impact. Small fills may directly eliminate individual plants and animals, whereas larger fills may destroy local populations or entire communities. In general, small nonmigratory species will be more susceptible to disturbance than larger animals, which may merely be displaced. Landfilling operations and concomitant disturbances will frequently preclude the use of the area by wildlife. Small localized operations will probably not be

characterized by long-range detrimental effects on plant and animal communities. However, key wildlife habitat areas, such as calving, bear denning, or mineral lick areas, should not be utilized. Indirect effects of landfilling operations stem primarily from changes in air and water quality and from excessive heavy equipment noise. Decreasing air and water quality may affect local plant and animal communities, whereas industrial noise, especially during critical times (e.g. breeding season, migration season), can influence wildlife distribution and abundance.

Many of the detrimental results discussed in greater detail in the section on the effects of vegetation removal (Section II.D.2) and the effects of pollutants on plant and animal species (Section II.D.3) must be taken into consideration and clearly evaluated before landfilling is considered. Because clearing and grubbing frequently precedes landfilling, the plant and wildlife impacts discussed in Section II.D are also pertinent and should be considered as possible outcomes of landfilling operations.

e. Aquatic Biology

Construction filling on land does not normally affect the aquatic environment. However, activities conducted during rainstorms or without proper erosion control could result in the impacts discussed in Section II.E.1.

f. Soils

Construction fill on land is anticipated to have the following effects on the soil characteristics of a site.

(1) Accelerated Erosion and Sedimentation — Fill material can be highly susceptible to erosion. The bare fill material is subject to the unbuffered mechanical effects of wind and rain, with consequent erosional effects. In addition, fill materials are at times difficult to revegetate, particularly if they are of dredge spoils. The longer the fill remains unvegetated, the greater the potential for erosion.

(2) Subsidence — Fill on organic soils can lead to long-term subsidence due to the high bulk, low strength, and unstable nature of the soil. Also, some fill materials are organic (e.g. trees, roots, shrubs, wood) and are therefore decomposable. Over time, decomposition of these materials will lead to reduced volume of the fill and consequent subsidence and soil instability and their use is therefore inadvisable.

(3) Changes in the Biological, Chemical, and Physical Properties of the Soil pH — The soil system previously residing on the fill site will be smothered and essentially destroyed, and will be replaced by an immature soil system having an undeveloped soil fauna. The soil system eventually developed on the site over time will depend on the

climatic conditions and the fill material, but will probably differ from surrounding soils, resulting in a permanent change in the biotic community of the site.

g. Interactions

Potential consequences of construction filling on land on interactions are itemized as follows:

(1) Increased sediment and nutrient transfer from terrestrial to aquatic systems can occur. Potential secondary effects are a reduction in spawning habitat, alteration in makeup of benthic communities, decreased light penetration with possible localized reduction in primary production, and increased nutrient concentrations with subsequent changes in productivity.

(2) Some possibility of accidental spill of toxic substances, particularly petrochemical products, may occur. Through incomplete combustion and engine drip, small quantities can be expected to find their way to aquatic systems. Petroleum contaminants have both immediately lethal and chronically toxic effects on biota. Secondary effects are also deleterious (e.g., interference with gas exchange at water surface and matting of fur or feathers, with subsequent loss in insulation and/or buoyancy).

(3) In areas of seasonal concentrations, disturbance of migratory species by noise, habitat removal, or presence of humans can have significant adverse effects on regional, statewide, and nationwide populations.

IMPACT ANALYSIS, CONSTRUCTION FILLING ON LAND

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-45 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL				1,2,3,4,5,6	1a 3a,b,d					1	1a 2c,d	2j 5a;6	1b,c		1,c,d	1,a,b,c	5,6,7 8a,c	2,3 8a	8,d	6b	2a 4a	2,c
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,j	2a,j	1b,c 6			1	2,3,4,5,6,7 8b,c	8a	8,d	4a	2a,c	6b
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,j	2j	1b,c 3b;6			1	2,3,4,7 8b	5 8,c	6 8a	4a		2a,c
B. NORTHWEST	CL				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2a,j	6		1b,c 2c,j;3b		1	5,7 8b,c	2,3 8a	8,d		2a 4a;6b		2,c
	CU				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2a,d,j	2j		1b,c 6		1	2,3,4,7 8b,c	6 8a	8,d	4a	2a		2,c 6b
	IL	1			2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,j		1b,c 6		1	7 8b,c	2,3,4,5 8a					2a,c 4a;5a
	IU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,j		1b,c 6		1	7 8b,c	2,3,4,5 8a,b					2a,c 4a;5a
	SM				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j	2j		1b,c 3b;6		1	2,3,4,7 8b	5 8,c	6 8a	4a			2a,c
C. UPPER YUKON/ PORCUPINE	IL	1			2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j;6	2d		1b,c 2j		1	5,7 8b,c	8a	2,3 8,d	6b	2,c	2a 4a;5a	
	IU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j;6	2d,b		1b,c 2j		1	2,3,4,7 8b,c	5 8a	8,d	4a	2a 6b	2,c 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2c,d,j			1b,c 2j;6		1	2,4	3,5,7	8a,b	4a	2a,c		
D. TANANA	IL	1 2a,c,d	2b 3		4,5,6	1b 3a,b,d				1,6	1a 3a,j	2c,d		1b,c 2j;6		1		5 8a,b,c,d	2,3,7		2,c	2a 4a;5a	
	IU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e,g,h		1b,c 2j;6		1		2,3,4,7 8a,b,c	5 8,d		2,c 4a;6b	2a 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j			1b,c 6		1	2,4	5,7	8a,b	4a	2,c	2a	
E. YUKON/KOYUKUK	IL	1			2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	6		1b,c 2c,d,j		1		2,3,5,7 8a,b,c	8,d		2,c 6b	2a 4a;5a	
	IU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e		1b,c 2j;6		1	2,3	4,7 8a,b,c	5 8,d		2,c 4a	2a 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j			1b,c 6		1	2,3,4	5,7	8a,b	4a	2,c	2a	
F. YUKON/ KUSKOKWIM DELTA	CL				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2j			1b,c 2c,d,j		1	5,7	2,3 8a,b,c	8,d	6b	2,c 4a	2a	
	CU				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e		1b,c 2j;6		1	2,3,4,7	5 8a,b,c	8,d		2,c 4a	2a	
	SM				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2c,d,j			1b,c 2j;6		1		2,3	4,5,6 8a,b,c,d		2a,c 4a		
G. UPPER KUSKOKWIM	IL	1			2,3,4,5,6	1b 3a,b,d				1,6	1a 2a,j	2c,d		1b,c 2j;6		1		5 8a,b,c	2,3,7		2,c	2a 4a;5a	
	IU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e,g,h		1b,c 2j;6		1		2,3,4,7 8a,b,c	5 8,d		2,c 4a;6b	2a 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j			1b,c 6		1	2,3,4	5,7	8a,b	4a	2,c	2a	
H. COOK INLET	CL	1 2a,c,d	2b 3		4,5,6	1b 3a,b,d			1	6	1a 2j	2c,d,e		1b,c 2j;6		1,d,e	1,a,b,c,f		8a,b,c	2,3,6 8,d		2,c	2a 4a;5a
	CU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e		1b,c 2j;6		1		2,3,4 8a,b,c	6 8,d		2,c 4a	2a 5a	
	IL	1			2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e		1b,c 2j;6		1	5,7	2,3,4 8a,b,c	8,d		2,c 4a	2a 5a	
	IU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j	2g		1b,c 2j;6		1		2,3,4,7 8a,b,c	6 8,d		2,c 4a	2a 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2c,d,j			1b,c 6		1	2,3,4		8a,b,c,d		2a,c 4a		
I. COPPER RIVER	IL	1			2,3,4,5,6	1b 3a,b,d			6	1	1a 2a,j			1b,c 2c,d,e,j;6		1	5,7	2,3 8a,b,c	8,d		2a,c 4a	2a 5a	
	IU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2a,j	2c,d,e		1b,c 2j;6		1		2,3,4,7 8a,b,c	6 8,d		2a 4a	2,c 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2c,d,j			1b,c 2j;6		1	2,3,4	5,7	8a,b,c,d		2a,c 4a		
J. ALEUTIAN	CL				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j	2j		1b,c 6		1			2,3,4,5 8a,b,c,d		6b	2a,c 4a;5a	
	CU				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j			1b,c 6		1		2	3,6 8a,b,c,d	6b	2a	2,c 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2c,d,j			1b,c 2j;6		1	2,3,4		8a,b,c,d		2a,c 4a		
K. BRISTOL BAY	CL		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j			1b,c 2c,d,e,j;6		1,d,e	1,a,b,c,f		2,3,5,6 8a,b,c,d	6b		2a,c 4a;5a	
	CU				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e		1b,c 2j;6		1		2,3,4	5,6 8a,b,c,d		4a	2a,c 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2c,d,j			1b,c 2j;6		1	2,3,4		8a,b,c,d		2a,c 4a		
L. KODIAK/SHELIKOF	CU		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,j	6	1b,c 2j;6		1		2,3	4,5,6 8a,b,c,d	6b	4a	2a,c 5a	
	SM				1,2,3,4,5,6	1b 3a,b,d			6	1	1a 2c,d,j			1b,c 2j;6		1	2,3,4		8a,b,c,d		2a,c 4a		
M. GULF OF ALASKA	CL/ CU		1,2,3		4,5,6	1b 3a,b,d			6	1	1a 2j	2c,d,e		1b,c 2j;6		1,d,e	1,a,b,c,f	2,3,4	6 8a,b,c	8,d	6b	2a,c 4a	5a
	SM		1		2,3,4,5,6	1b 3a,b,d				1,6	1a 2j	2c,d,e		1b,c 2j;6		1	2,4	3 8b	8a,b,c,d	6b	4a	2a,c 5a	
N. SOUTHEAST	CL		1,3		2,4,5,6	1b 3a,b,d				1,6	1a 2j			1b,c 2c,d,e,j;6		1			2,3 8a,b,c,d	6b	2,c	2a 4a;5a	
	CU		1,2,3		4,5,6	1b 3a,b,d			6	1	1a 2j	2c,d,e		1b,c 2j;6		1,d,e	1,a,b,c,f	2,3,4	6 8a,b,c		6b	2a,c 4a	
	SM				1,2,3,4,5,6	1b 3a,b,d				1,6	1a 2c,d,j			1b,c 2j;6		1	2,3,4		8a,b,c,d		2,c 4a	2a	

D. FOUNDATION CONSTRUCTION

1. Introduction

Foundations channel concentrated structural loads to the ground where they are evenly distributed. Permafrost requires special care in the planning of foundations, particularly in discontinuous zones where ground temperatures range between minus 5 degrees C (23 degrees F) and minus 1.5 degrees C (29 degrees F). In these areas, any slight warming of the soil can produce a great change in soil conditions which the foundation must be designed to withstand. Warmth from a building penetrates the ground and thaws the permafrost, causing the surface grade to fall and the building to settle. The most significant local factors are sunlight exposure, vegetative cover, and soil drainage. Ideally, in the discontinuous zone the site should be located on the south side of a hill composed of coarse materials and sparsely covered with vegetation. Such a site is usually warm and dry enough to permit conventional footing foundations used in temperate zones. However, under less favorable conditions, pile foundations are necessary to attach the structure to the permafrost and to resist the upward heaving action of the active layer.

2. Resources Required to Complete Action

In addition to equipment and manpower, concrete, steel and wood are resources used.

3. Permits and Regulations

Within city or borough jurisdiction, the Uniform Building Code (1973) provides the standards for foundation construction. In the city and borough of Anchorage, the *Standard Construction Specifications* (1973) amend the Uniform Building Code.

4. Description of Action and Equipment

A core drill is used to investigate the depth of the permafrost and active layer, the soil composition, the water content of the soil, and the presence of hard rock and ice lenses. In discontinuous permafrost areas, measurements to the nearest foot are required to locate the foundation site. When the site is underlain by permafrost, three techniques may be used to minimize the effects of the frozen ground: ice excavation and removal, insulation, and refrigeration.

The first technique is called elimination and may be used when the depth of permafrost is not excessive. In such soil, footing foundations may be built with or without basements. The second technique includes the maintenance of the permafrost through separation from the heated building. The layer of cold air beneath the floor of a structure

built on pilings maintains the temperatures necessary for permafrost. The building must be insulated, and gravel may be placed on the ground surface to further reduce heat conduction. The third technique involves insulation with refrigeration to maintain the frozen soil. This method is more costly than the first two, but avoids setting pilings deep in the permafrost, and thus speeds the construction process.

To implement these techniques, two methods of building foundations are used — excavation and pile setting. In the first method, an entire basement is excavated to undisturbed soil below the active layer, which is commonly less than 8 feet. Steel-reinforced concrete footings and walls line the excavation. Occasionally, footings and piers are built to support a building without a basement. In this case the excavation is less extensive, but must be below the active layer. Pile setting is achieved with comparatively little surface disturbance. Ideally, this operation occurs in the spring when the ground surface is still frozen, and the permafrost has sufficient time to freeze around the pilings before construction begins in summer. The site is cleared by hand and the insulating moss cover is disturbed as little as possible. Gravel may be placed over the moss to increase insulation and maintain the permafrost below. Pilings may be placed by either drilling or steaming and driving.

The steaming and driving process is the easiest and often the quickest way to anchor the piles firmly. This process provides high-pressure steam to blow the sand and other fine materials out of the hole. Each hole requires about 3 hours of steam and the jetting pipe may need to be hammered through material which cannot be blown out of the thawing soil. Generally, the piles are driven through the active layer and 10 feet into the permafrost. After 4 months, the piles are satisfactorily frozen and are capable of withstanding the expansive heaving of the active layer in the fall. Construction of the building occurs during the next warm season. Drilling is used when the permafrost might be damaged by steaming or when a building must be built quickly after the foundation sets. Drilling piles do not need to be driven, and the sand slurry placed around them in the hole will refreeze more rapidly than in steamed holes.

5. Impacts

a. Air Quality

The most important emissions to the atmosphere are those from the operation of heavy-duty machinery. Those emissions, previously tabulated in Table IV-V, include carbon monoxide, hydrocarbons, nitrogen oxides, particulates, and sulfur oxides. Certain types of pile driving involve the possible emission of fugitive dust and may be of particular importance in depositing this dust on surrounding snow cover and hastening snowmelt.

b. Noise

The foundation phase of construction is somewhat less noisy than other phases. The two noisiest pieces of equipment for various types of projects are shown in Table IV-VIII, together with the noise levels as measured at 50 feet. For some types of foundations, impact equipment and tools are required for placement and driving of piles. Conventional pile drivers are either steam- or diesel-powered. In both cases, the impact of the hammer/pile interaction is the dominant noise component. These noise levels are difficult to measure or project due to the fact that the levels are affected by the pile type and length, but peak levels are approximately 100 dBA at 50 feet. Composite noise ranges associated with foundation work at various project sites are shown in Table IV-IX and include all equipment normally employed during this construction phase.

c. Water Resources

Excavation or surface disturbance prior to the placement of the foundation structure may present a potentially erodible surface by precipitation and stormwater runoff. An increase over natural concentrations of suspended material could result in the impacts identified in Section II.C.1 and cause a change in the pH of the receiving water, as discussed in Section II.C.4.

d. Terrestrial Biology

Construction of foundations poses the same problems to plants and animals that numerous other engineering actions (e.g., excavation) are expected to pose. Foremost among these are the complete destruction of vegetation within the immediate construction site and the additional destruction and/or damage to vegetation resulting from the emission of noxious gases, accidental spillage of fuel, and discarded refuse. In addition to these three impacts, animals would also be influenced by the noise from the steaming and driving operation. Impacts on animals, however, would primarily be determined by the season of construction. Construction before the breeding and nesting season of birds and/or the calving season of ungulates would reduce the detrimental impact of construction.

Some of the secondary (and frequently long-range) impacts of foundation construction occur with the removal of vegetation and changes in land use patterns. These are clearly described in Section II.D.

e. Aquatic Biology

Foundation construction does not normally affect the aquatic environment. However, activities conducted during rainstorms or without proper erosion control could result in the impacts discussed in Section II.E. Salmon spawning areas may be affected by

TABLE IV-VIII. NOISIEST EQUIPMENT TYPES OPERATING
AT CONSTRUCTION SITES DURING THE FOUNDATION PHASE

<u>Type of Project</u>	<u>Type of Equipment</u>	<u>Noise Level</u>
Domestic housing	Concrete mixer	85 dBA
	Pneumatic tools	85 dBA
Office buildings	Jackhammer	88 dBA
	Concrete mixer	85 dBA
Industrial	Jackhammer	88 dBA
	Concrete mixer	85 dBA
Public works	Truck	91 dBA
	Scraper	88 dBA

Source: Bolt, Beranek, and Newman, 1971a

TABLE IV-IX. TYPICAL RANGES OF NOISE LEVELS AT
VARIOUS CONSTRUCTION SITES DURING FOUNDATION PHASE

Type of Project	Energy Level, dB(A) *	
	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site
Domestic housing	81	81
Office buildings, hotels, hospitals, and schools	78	78
Industrial parking garage, recreation sites, stores, and service stations	77	77
Public works, roads, highways, sewers, and trenches	88	88

* 50 dBA ambient

Source: Bolt, Beranek, and Newman, 1971a

the removal of gravel (Section II.E.4) from streambeds for foundation insulation in permafrost areas.

f. Soils

Those impacts attributed to clearing and grubbing and excavation are applicable to foundations. An additional impact is that foundations generally include coverage of the site with impervious material and essentially permanently remove the soil covered from use in the surrounding ecosystem.

g. Interactions

Those interaction impacts which were identified for excavation are also applicable to construction of foundations.

IMPACT ANALYSIS, FOUNDATION CONSTRUCTION

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL				1,2,3,4,5,6	1b 2c,d					1	1a 2c,d	2i 5a;6	1b,c 4b		1c,d	1a,b,c 4a	5,6,7 8b,c	2,3 8a	8d	6b	2a 4a	2c
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,j	2c,i	1b,c 4b;6			1 4a	2,3,4,5,6,7 8b,c	8a	8d	4a	2a,c	6b
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d	2i	1b,c;3b 4b;6			1 4a	2,3,4,7 8b	5 8a	6 8a	4a		2a,c
B. NORTHWEST	CL				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,j	6	1b,c;2c,i 3b;4b			1 4a	5,7 8b,c	2,3 8a	8d		2a 4a;6,b	2c
	CU				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,d,e,i	2i	1b,c 4b;6			1 4a	2,3,4,7 8b,c	5 8a	8d	4a	2a	2c 6b
	IL	1			2,3,4,5,6	1b 3a,b,d					1,8	1a 2j	2c,d,e,i	1b,c 4b;6			1 4a	7 8b,c	2,3,4,5 8a,b				2a,c 4a;5a
	IU		1		2,3,4,5,6	1b 3a,b,d					1,8	1a 2j	2c,d,e,i	1b,c 4b;6			1 4a	7 8b,c	2,3,4,5 8a				2a,c 4a;5a
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d	2i	1b,c;3b 4b;6			1 4a	2,3,4,7 8b	5 8a	6 8a	4a		2a,c
C. UPPER YUKON/ PORCUPINE	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i;6	2d	1b,c 2i;4b			1 4a	5,7 8b,c	8a	2,3 8d	6b	2c	2a 4a;5a
	IU		1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i;6	2d,h	1b,c 2i;4b			1 4a	2,3,4,7 8b,c	5 8a	8d	4a	2a 6b	2a 5a
	SM				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2c,d,e,i		1b,c;2i 4b;6			1 4a	2,4	3,5,7	8a,b	4a	2a,c	
D. TANANA	IL	1	2a,c,d	2b 3	4,5,6	1b 3a,b,d					1,6	1a 2a,j	2c,d	1b,c;2i 4b;6			1 4a		5 8a,b,c,d	2,3,7		2c	2a 4a;5a
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e,g,h	1b,c;2i 4b;6			1 4a		2,3,4,7 8a,b,c	5 8d		2c 4a;6,b	2a 5a
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i		1b,c 4b;6			1 4a	2,4	5,7	8a,b	4a	2c	2a
E. YUKON/KOYUKUK	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2f,j	6	1b,c 4b;2c,d,e,i			1 4a		2,3,5,7 8a,b,c	8d		2c 6b	2a 4a;5a
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e	1b,c;2i 4b;6			1 4a	2,3	4,7 8a,b,c	5 8d		2c 4a	2a 5a
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i		1b,c 4b;6			1 4a	2,3,4	5,7	8a,b	4a	2c	2a
F. YUKON/ KUSKOKWIM DELTA	CL				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2j		1b,c 2c,d,e,i;4b			1 4a	5,7	2,3 8a,b,c	8d	6b	2c 4a	2a
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e	1b,c;2i 4b;6			1 4a	2,3,4,7	5 8a,b,c	8d		2c 4a	2a
	SM				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2c,d,e,i		1b,c;2i 4b;6			1 4a		2,3	4,5,6 8a,b,c,d		2a,c 4a	
G. UPPER KUSKOKWIM	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,j	2c,d	1b,c;2i 4b;6			1 4a		5 8a,b,c	2,3,7		2c	2a 4a;5a
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e,g,h	1b,c;2i 4b;6			1 4a		2,3,4,7 8a,b,c	5 8d		2c 4a;6,b	2a 5a
	SM				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i		1b,c 4b;6			1 4a	2,3,4	5,7	8a,b	4a	2c	2a
H. COOK INLET	CL	1	2a,c,d	2b 3	4,5,6	1b 3a,b,d				1	6	1a 2j	2c,d,e	1b,c;2i 4b;6		1d,e	1a,b,c,f 4a		8a,b,c	2,3,6 8d		2c	2a 4a;5a
	CU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e	1b,c;2i 4b;6			1 4a		2,3,4 8a,b,c	6 8d		2c 4a	2a 6a
	IL	1			2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e	1b,c;2i 4b;6			1 4a	5,7	2,3,4 8a,b,c	8d		2c 4a	2a 5a
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i	2g	1b,c;2i 4b;6			1 4a		2,3,4,7 8a,b,c	6 8d		2c 4a	2a 5a
	SM				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2c,d,e,i		1b,c 4b;6			1 4a	2,3,4		8a,b,c,d		2a,c 4a	
I. COPPER RIVER	IL	1			2,3,4,5,6	1b 3a,b,d				6	1	1a 2a,j		1b,c;4b 2c,d,e,i;6			1 4a	5,7	2,3 8a,b,c	8d		2a,c 4a	6a
	IU			1	2,3,4,5,6	1b 3a,b,d					1,6	1a 2a,j	2c,d,e	1b,c;2i 4b;6			1 4a		2,3,4,7 8a,b,c	6 8d		2a 4a	2c 6a
	SM				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2c,d,e,i		1b,c;2i 4b;6			1 4a	2,3,4	5,7	8a,b,c,d		2a,c 4a	
J. ALEUTIAN	CL				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i	2i	1b,c 4b;6			1 4a			2,3,4,5 8a,b,c,d		6b	2a,c 4a;5a
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2c,d,e,i		1b,c 4b;6			1 4a		2	3,6 8a,b,c,d	6b	2a	2c 6a
	SM				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2c,d,e,i		1b,c;2i 4b;6			1 4a	2,3,4		8a,b,c,d		2a,c 4a	
K. BRISTOL BAY	CL		1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2j		1b,c;4b 2c,d,e,i;6		1d,e	1a,b,c,f 4a			2,3,6 8a,b,c,d	6b		2a,c 4a;5a
	CU				1,2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e	1b,c;2i 4b;6			1 4a		2,3,4	5,6 8a,b,c,d		4a	2a,c 6a
	SM				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2c,d,e,i		1b,c;2i 4b;6			1 4a	2,3,4		8a,b,c,d		2a,c 4a	
L. KODIAK/SHELIKOF	CU		1		2,3,4,5,6	1b 3a,b,d					1,6	1a 2j	2c,d,e,i 6	1b,c 4b			1 4a		2,3	4,5,6 8a,b,c,d	6b	4a 5a	2a,c
	SM				1,2,3,4,5,6	1b 3a,b,d				6	1	1a 2c,d,e,i		1b,c;2i 4b;6			1 4a	2,3,4		8a,b,c,d		2a,c 4a	
M. GULF OF ALASKA	CL/ CU		1,2,3	4,5,6		1b 3a,b,d				6	1	1a 2j	2c,d,e	1b,c;2i 4b;6		1d,e	1a,b,c,f 4a	2,3,4	5 8a,b,c	8d	6b	2a,c 4a	6a
	SM		1	2,3,4,5,6		1b 3a,b,d					1,6	1a 2j	2c,d,e	1b,c;2i 4b;6			1 4a	2,4	3 8b	8a,c,d	6b	4a	2a,c 6a
N. SOUTHEAST	CL		1,3	2,4,5,6		1b 3a,b,d					1,6	1a 2j		1b,c;4b 2c,d,e,i;6			1 4a			2,3 8a,b,c,d	6b	2a	2a 4a;5a
	CU		1,2,3	4,5,6		1b 3a,b,d				6	1	1a 2j	2c,d,e	1b,c;2i 4b;6		1d,e	1a,b,c,f 4a	2,3,4	5 8a,b,c		6b	2a,c 4a	6a
	SM			1,2,3,4,5,6		1b 3a,b,d					1,6	1a 2c,d,e,i		1b,c;2i 4b;6			1 4a	2,3,4		8a,b,c,d		2a 4a	2a

E. CONSTRUCTION FILLING IN WATER AND WETLANDS

1. Introduction

Construction filling in water and wetlands occurs when solid material is used to construct breakwaters for harbor protection or to reclaim land for building purposes. Fill materials include soil, rock, rubble waste, dredged spoil, and sanitary solid waste.

2. Resources Required to Complete Action

Major emphasis on the quality of fill material is placed on the compactability of the material for support and the ability of the fill material to resist continuous wave action. The selection of fill material is usually determined by the water depth, bottom conditions, and equipment required for the fill operation. In the case of a breakwater, the core material of waste rock and sand extends above the water level and is then covered with an envelope of small crushed rock and gravel (filter course) to prevent the core material from washing out. Armor rock (15 to 20 tons) overlays the filter course. All materials are selected for both their availability and the wave climate design.

3. Permits and Regulations

The placement of fill material in water and wetlands is controlled by city, borough, state, and federal agencies. The Alaska Department of Natural Resources and the Department of Fish and Game require permit approval for construction filling in wetlands, and the U.S. Corps of Engineers requires permit approval for filling in navigable waters.

4. Description of Action and Equipment

Fill material and dredged spoil are two principal methods of construction filling in waters and wetlands. The former is utilized in interior regions, and a combination of mass dumping and spoil disposal is used in marine and river water bodies. Suitable fill material is spread over the site and compacted in layers to grade and site line specifications. Machinery requirements are similar to those identified for landfilling and dredging operations. The use of truck or barge cranes may be required for placement of large rocks or concrete blocks.

5. Impacts

a. Air Quality

The major source of emissions to the atmosphere from landfill operations results from the activities involved in extraction, transport, and processing of fill materials. Particulates are blown from the loads of dump trucks and road dust is stirred up by the

movement of vehicles on the bare surface. Control techniques involve watering, chemical stabilization, and reduction of surface wind speed using windbreaks or source enclosure. The quantity of suspended dust emissions in pounds per ton of fill may be estimated by the following expression:

$$\text{Emissions Factor} = \frac{0.33}{(\text{PE}/100)^2}$$

where

PE = Thornthwaite's precipitation/evaporation index
(U.S. Environmental Protection Agency, 1975)

Gaseous emissions from the vehicles used in the operations may be estimated from values previously given in Table IV-V.

b. Noise

Filling operations generally create a short-term noise impact ranging from an average of 79 to 88 dB(A) at 50 feet with all pertinent equipment present at the site. The major noise sources are associated with earth-moving equipment and engine-powered materials handling equipment. Engine noise typically predominates, with exhaust noise usually being most significant, and inlet and structural noise being of secondary importance.

c. Water Resources

The deposition of fill material can be expected to increase the turbidity of the water due to the composition of the fill material and the resuspension of bottom sediments, resulting in the impacts discussed in Section II.C.1. Any organic matter in the fill material can be expected to depress dissolved oxygen concentrations (Section II.C.3). Freshly exposed rock surfaces of fill material may contribute metal concentrations in excess of natural conditions (Section II.C.2).

d. Terrestrial Biology

The act of filling on riparian vegetation or wetlands covers low-lying vegetation and the root systems of trees, killing both. The trees often remain as dead snags. Generally, revegetation on dredge spoil material is slow as compared to other disturbance types. Riparian and wetland community types would be initially replaced by site-dependent terrestrial early-successional communities. These communities would, in turn, be invaded by site-dependent later-successional communities. Such communities would represent different

assemblages of plant and animal species as compared to the original riparian and wetland communities.

Wetlands in the conterminous United States have been measurably reduced by filling. Estimates of 40 to 100 million acres (one third to one half of the United States wetlands) of reclaimed wetlands have been discussed in various studies (Harmon, 1968; U.S. Department of Agriculture, 1965; Shaw and Fredine, 1956). Many of these have been lost by filling. The filling of wetlands reduces the regional carrying capacity for wetland-dependent species. The ability of a region to support wetland-dependent organisms would therefore be impaired.

With the reduced waterfowl breeding habitat within the conterminous United States, Alaska's wetlands become even more valuable as waterfowl breeding areas. In dry years, when many wetlands dry up in Canada and the midwestern United States, Alaskan wetlands are even more intensely used (Fortenbery, 1974). Waterfowl of Alaskan origin provided approximately 13 percent of the 100,000,000 waterfowl annually harvested within the United States between 1956 and 1962 (U.S. Department of Agriculture, 1975).

Historically, estuarine wetlands have been severely affected by man's activities, particularly filling. For the total continental United States, 23 percent of the estuaries have been moderately modified (U.S. Fish and Wildlife Service, 1970). Estuaries are important to a number of migratory species. The extent to which anadromous fish fry and juvenile crustaceans utilize estuarine marshes in Alaska is undocumented. In other estuaries, the marshes have proven to be important rearing grounds for similar species (Odum, 1971). Filling of estuaries reduces the regional estuarine carrying capacity.

e. Aquatic Biology

The primary impact of the deposition of fill material occurs as aquatic habitat is covered and thus precluded from future aquatic production. The severity of this destruction depends upon the importance of the area for breeding, feeding, or migrating functions of existing species. The destruction of salmon spawning areas will directly decrease future production from the area since specific physical characteristics are required for salmonid reproduction.

Secondary effects occur as silt and turbidity are increased in the project vicinity due to the dispersal of fill materials. This increased turbidity decreases light penetration and covers plant surfaces, thereby reducing photosynthesis and plant production. Benthic organisms may also be killed or suffer reduced growth if they are covered by sediment. Although fish can survive relatively high amounts of suspended matter for short periods, chronic exposure (such as from resuspended sediments in backwater areas)

may destroy gill tissue and interfere with respiration. Salmonid species are generally more sensitive to suspended sediment than other species.

Fill material contaminated with pesticides, metals, acids, or alkalines may release toxins to surrounding waters and thus chronically affect the life processes of nearby organisms. These materials may be transferred to terrestrial food chains as wildlife harvest aquatic species. Fill in marine or estuarine waters may cause sedimentation, which blankets shellfish or interferes with their growth, reproduction, or respiration. Excessive turbidity may also inhibit critical fish movements such as salmon migration.

Long-term effects on aquatic production occur due to the accessibility which fill operations normally enhance. Additional human use of an area generally results in increased fishing and other activities not conducive to optimum aquatic productivity.

f. Soils

Fill on water and wetlands is anticipated to have the following effects.

(1) Accelerated Erosion and Sedimentation — Fill material can be highly susceptible to erosion. The bare fill material is subject to the unbuffered mechanical effects of wind and rain, with consequent erosional effects. In addition, fill materials are at times difficult to revegetate, particularly if they are of dredge spoils. The longer the fill remains unvegetated, the greater the potential for erosion.

(2) Subsidence — Filling on wetlands and subsequent use of the area for development, particularly peat bogs and fen, can lead to long-term subsidence. Many wetlands are underlain by highly organic soils which slowly decompose and mineralize over time. In an undisturbed wetland, organic material is continuously added to the soil, compensating for the loss. However, filling the wetlands precludes the introduction of organic material and places these high bulk soils under stress. Predictably, subsidence follows. Also, some fill materials are putrescible and over time will reduce their volume. Consequently, fills containing these materials are highly unstable.

(3) Changes in the Biological, Chemical, and Physical Properties of Soil — The wetland soils system will be replaced by the fill material which can have diverse physical and chemical properties and will have an undeveloped soil biology. Reformation of a soil system will depend on the climatic conditions and type of spoil material used.

g. Interactions

The potential consequences of fill on water and wetlands are itemized as follows:

(1) Fills placed near or at the water edge would result in temporary increases in sediment and nutrient transfers from terrestrial to aquatic systems. The transfers are a result of the unvegetated bare nature of the fill material, which remains prone to erosion by surface water runoff until revegetated. Revegetation on fill sites is generally slower than revegetation on other disturbed sites. Potential secondary effects are reduction in spawning habitat, alteration in makeup of benthic community, increased turbidity, and increased nutrients.

(2) The filling on water results in greatly increased suspended sediments. Such sediments can cause mechanical impediment to gills or other breathing structures, resulting in suffocation. If timing of downstream migration of juvenile anadromous fish coincides with the presence of high concentrations of suspended sediments, substantially increased mortalities are predictable.

(3) Filling of wetlands has several hydrologic effects that result in reduced low flows and increased high flows. Wetlands act like a sponge in hydrologic systems and buffer stream flows. They can absorb large quantities of water and generally provide a wide surface for drainage during wet conditions and release water during dry conditions. Removal of the wetland can result in flooding downstream during wet periods and reduction of flows during dry periods. The degree of the effect is dependent on local conditions.

(4) In areas of seasonal concentrations, disturbance of migratory species by noise, habitat removal, or presence of humans can have significant adverse effects on regional, statewide, and nationwide populations.

(5) Some possibility of accidental spill of toxic substances, particularly petrochemical products, may occur. Through incomplete combustion and engine drip, small quantities can be expected to find their way to aquatic systems. Petroleum contaminants have both immediately lethal and chronically toxic effects on biota. Secondary effects are also deleterious (e.g., interference with gas exchange at water surface and matting of fur or feathers, with subsequent loss in insulation and/or buoyancy).

IMPACT ANALYSIS, CONSTRUCTION FILLING IN WATER AND WETLANDS

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a;6b		5a
	CU				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a	6b	5a
	CL				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
B. NORTHWEST	CL				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a	6b	5a
	CU				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	IL	1			2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	IU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
C. UPPER YUKON/ PORCUPINE	IL	1			2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a 2j		1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a;6b		5a
	IU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
D. TANANA	IL	1 2a,c,d	2b 3	4,5,6	1b 2a,b,d				1,3,4,6			1a 2j		1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	IU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
E. YUKON/KOYUKUK	IL	1			2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a	6b	5a
	IU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
F. YUKON/ KUSKOKWIM DELTA	CL				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a 2j		1a,b,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a;6b		5a
	CU				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
G. UPPER KUSKOKWIM	IL	1			2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	IU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
H. COOK INLET	CL	1 2a,c,d	2b 3	4,5,6	1b 2a,b,d				1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	CU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
	IL	1			2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3			2a 4a		5a
	IU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
I. COPPER RIVER	IL	1			2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
	IU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
J. ALEUTIAN	CL				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a;6b		5a
	CU				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
K. BRISTOL BAY	CL		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a;6b		5a
	CU				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			3	2		2a 4a		5a
L. KODIAK/SHELIKOF	CU		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a		5a
M. GULF OF ALASKA	CU/ CU		1,2,3	4,5,6	1b 2a,b,d				1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a;6b		5a
	SM		1		2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a;6b		5a
N. SOUTHEAST	CL		1,3	2,4,6	1b 2a,b,d				1,3,4,6			1a	2j	1a,c 2a;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a;6b		5a
	CU		1,2,3	4,5,6	1b 2a,b,d				1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a;6b		5a
	SM				1,2,3,4,5,6	1b 2a,b,d			1,3,4,6					1a,b,c 2j;k;6	1a,b,c,d,e 3a;4a,b;6			2,3			2a 4a;6b		5a

F. DREDGING

1. Introduction

Dredging is underwater excavation required to maintain adequate water depths in navigation channels and dock areas, to develop port and industrial facilities, and to obtain fill material. The dredged material (spoil) may be deposited on land or in water, depending upon the chemical quality of the sediments.

2. Resources Required to Complete Action

The resources required for a dredging operation are the dredging equipment and an acceptable spoil disposal site.

3. Permits and Regulations

State and federal resource and regulation agencies have imposed restrictions for dredging operations. The principal agencies are the Environmental Protection Agency, U.S. Corps of Engineers, Department of Fish and Game, Department of Environmental Conservation, and Department of Natural Resources. Coordination with these agencies will be required prior to initiating a dredging operation.

4. Description of Action and Equipment

The pipeline dredge and clamshell bucket are two principal methods of dredging in Alaskan waters. A pipeline dredge consists of a large centrifugal pump mounted on a specially designed barge. A suction pipe, equipped with a cutter head to break up bottom materials, is lowered to a controlled depth by cables from the barge. The cutter head is driven by a power source on the barge and the bottom material is sucked up through the pipe and pumped to a disposal site through a pipeline. On some dredges the cutter head is replaced by a water jet that breaks up or loosens the bottom sediments. (Pipeline dredges are measured by the diameter of the suction pipe. They range from small 4-inch sand pumpers to large 36-inch dredges.)

The clamshell bucket dredge is a float-mounted hoist that utilizes a bucket consisting of two similar halves which are hinged at the top. The other essential components include a barge or float, hoisting machinery, a swinging boom, and an anchoring system. Some dredges are also equipped with winches to shift barges to facilitate material disposal. Buckets are designed for hard or soft digging materials. Hard digging buckets are heavier and have a more powerful closing mechanism than soft digging buckets. This added weight generally necessitates a reduction in bucket capacity. Clamshell bucket dredges are not equipped with disposal pipelines like the pipeline dredges. They are dependent upon

auxiliary disposal equipment, which generally consists of barges and a supporting tug to move the barges to the disposal area.

5. Impacts

a. Air Quality

The primary source of emissions to the atmosphere from dredging operations is windblown dust from dredge spoils. If a coagulation compound is not used, these spoils may constitute a major source of fine-grained particulates. Much of the equipment employed in dredging is powered by diesel engines. These constitute a minor source of emissions of several pollutants. Average emission levels of diesel powered engines were previously shown in Table IV-V.

b. Noise

The major sources of noise from dredging operations are associated with the use of internal-combustion equipment, pumps, and compressors, and engine-powered earth-moving equipment for remote spoil disposal. Stationary equipment, such as pumps or compressors, generally runs continuously at relatively constant power and speed. Noise levels at 50 feet range from about 70 to 80 dB(A), with pumps typically at the low end of the range. Earth-moving equipment, including trucks, shovels, and front-loaders, generally creates noise levels which range from 73 to 96 dB(A) at 50 feet. The greatest potential for noise abatement of earth-moving equipment is achieved in quieting the engine by use of improved mufflers. These short-term impacts are often alleviated by truck routing along routes which will avoid humans or animals, which are noise-sensitive, and by scheduling such transports at times which do not interfere with human activities such as sleep.

c. Water Resources

Dredging activities have the potential for creating significant water quality degradation. The release of turbidity-producing and toxic materials and the depression of dissolved oxygen levels are the primary water quality problems associated with dredging. Turbidity created by dredging and spoil disposal has been shown to persist and spread considerable distance, particularly in rivers (Section II.C.1). In sediments containing significant quantities of organics, agitation or resuspension may reduce oxygen levels due to high initial oxygen demand (Section II.C.3). The exposure of unoxidized sludges adds to the oxygen demands placed on waters from other sources. Sulfides and other components from industrial wastes may reach toxic concentrations during dredging and disposal activities (Section II.C.2).

d. Terrestrial Biology

Underwater excavation would generally have few direct adverse impacts on terrestrial plant and animal communities. Indirect effects of air pollution, however, may be detrimental to both aquatic and terrestrial plants and animals. Noise may significantly alter wildlife behavior and affect rookeries. Disturbance due to noise and the presence of humans in pristine environments can result in reduced reproductive success, particularly if rookeries are affected. The incidence of abandonment and predation increases at breeding colonies which are so disturbed. Other secondary effects are discussed in the subsection on interactions, below.

e. Aquatic Biology

The disturbance of bottom materials by dredging operations or through the discharge of spoil materials may affect aquatic life, as discussed in Section II.E.1. Dredging may also directly remove gravel or other substrates required for successful spawning. If organic material is released, dissolved oxygen levels may be lowered and the growth, activity, or development of aquatic organisms may be affected, as discussed in Section II.E.3.

f. Soils

No direct impacts on soils are anticipated by dredging activities. However, dredging that transect an area where materials are being moved along the coast (littoral drift), and can lead to erosion downdrift of the dredging site (Boscom, 1964; Baur, 1974) and subsequent loss of valuable land. Also, dredging as a method of draining peat wetlands can have indirect consequences due to the subsequent oxidation of the drained peat soils, which results in subsidence (Weir, 1950).

g. Interactions

The potential consequences of dredging are itemized as follows:

(1) Dredging in flowing waters, which results in deepened channels, alters the hydrodynamic regime of the water body. Changes in transport and scouring patterns can significantly alter deposition, temperature distribution, nutrient availability, dissolved oxygen distribution, and other environmental factors which influence aquatic ecosystems. Such changes in physical attributes can result in alterations in the plant and animal communities present at the channel site and adjacent areas, and in the erosional and accretional conditions of the site and adjunct areas.

(2) The dredging of channels in areas of coastal littoral drift (net transport of sediment along coast) can initiate erosional conditions downdrift of the channel. Areas downdrift of the channel will continue to move material along the coast; however, the continued supply of the source material will be cut off by a channel. Consequently, erosional conditions may result.

(3) In addition to the effects identified in subparagraph (1), above, deepened channels in estuaries can result in alterations in salinity and in the distribution of free-swimming larvae stages.

(4) High concentrations of suspended sediment during dredging and disposal can cause mechanical blockage of gills or other breathing structures, resulting in suffocation to some species. If timing of downstream migration of juvenile anadromous fish coincides with occurrences of high concentrations of suspended sediments caused by dredging or disposal, substantially increased mortalities are predictable.

(5) Channelization in streams and rivers can result in shortened stream length, alteration of normal runoff with increased peak flows and decreased low flows, reduction of aquatic fish and wildlife habitat, lowering of groundwater levels, reduction in wetlands, and downstream flooding. The specific effects and their magnitude are dependent on site specific conditions.

(6) Dredged material (most often hydraulic spoil) is frequently placed on wetlands and riparian habitats. For effects of this action, refer to Section IV.E, Construction Filling in Water and Wetlands.

IMPACT ANALYSIS, DREDGING

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	0																					
	CU	0																					
	SM	0																					
B. NORTHWEST	CL	2			1,2,3,4,5,6	3a,d	1,b		1	6	3	1a	2,j	1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	CU	0																					
	IL	0																					
	IU	0																					
	SM	0																					
C. UPPER YUKON/ PORCUPINE	IL	1	1		2,3,4,5,6	3a,d	1,b		1	6	3	1a 2,j		1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	IU	1		1	2,3,4,5,6	3a,d	1,b		1	6	3			1a,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	SM	0																					
D. TANANA	IL	1	1 2a,c,d	2,b 3	4,5,6	3a,d	1,b		1	6	3	1a 2,j		1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	IU	0																					
	SM	0																					
E. YUKON/KOYUKUK	IL	1	1		2,3,4,5,6	3a,d	1,b		1	6	3	1a	2,j	1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	IU	0																					
	SM	0																					
F. YUKON/ KUSKOKWIM DELTA	CL	2			1,2,3,4,5,6	3a,d	1,b		1	6	3	1a 2,j		1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	CU	0																					
	SM	0																					
G. UPPER KUSKOKWIM	IL	1	1		2,3,4,5,6	3a,d	1,b		1	6	3	1a	2,j	1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	IU	1												1a,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	SM	0																					
H. COOK INLET	CL	2	1 2a,c,d	2,b 3	4,5,6	3a,d	1,b		1	6	3	1a	2,j	1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	CU	0																					
	IL	0																					
	IU	0																					
	SM	0																					
I. COPPER RIVER	IL	0																					
	IU	0																					
	SM	0																					
J. ALEUTIAN	CL	0																					
	CU	0																					
	SM	0																					
K. BRISTOL BAY	CL	2		1	2,3,4,5,6	3a,d	1,b		1	6	3	1a	2,j	1,b,c 2,k;6	1a,b,c,d,e	3a 6	3	2		4a	2a 5a;6a		
	CU	0																					
	SM	0																					
L. KODIAK/SHELIKOF	CU	2		1	2,3,4,5,6	3a,d	1,b		1	6	3			1a,b,c 2,k;6	1a,b,c,d,e	3a 6	2,3			4a	2a 5a;6a		
	SM	0																					
M. GULF OF ALASKA	CU/ CU	2		1,3	2,4,5,6	3a,d	1,b		1	6	3	1a	2,j	1,b,c 2,k;6	1a,b,c,d,e	3a 6	2,3			4a	2a 5a;6a		
	SM	2		1	2,3,4,5,6	3a,d	1,b		1	6	3			1a,b,c 2,k;6	1a,b,c,d,e	3a 6	2,3			4a	2a 5a;6a		
N. SOUTHEAST	CL	2		1,3	2,4,5,6	3a,d	1,b		1	6	3	1a	2,j	1,b,c 2,k;6	1a,b,c,d,e	3a 6	2,3			4a	2a 5a;6a		
	CU	0																					
	SM	0																					

G. DRILLING FOR WATER

1. Introduction

Water is a renewable resource when the rate of withdrawal is less than the rate of recharge. Surface water and groundwater are presently used for domestic and industrial purposes in Alaska. The availability of groundwater varies throughout Alaska, depending on the geologic conditions. The primary producing zones or aquifers are sand and gravel areas situated between less permeable compacted layers of glacial till.

Most wells in the state have been drilled near Anchorage, and the city now operates eight large-capacity wells with a flow of 700 to 1500 gpm (1 to 2 million gallons per day). Fort Richardson and Elmendorf Air Force Base pump an average of 1.1 million gallons per day (mgd) from five wells, and the Central Alaska Utilities pumps an estimated 1.6 mgd from 22 wells. The remaining Anchorage residents are served by approximately 4000 individual wells which pump from 2 to 10 gpm.

2. Resources Required to Complete Action

Depending on the size and location of the well, the resources required for a drilling operation are the drilling and support equipment. In remote locations, camp facilities (crew quarters, communications, and cooking) and transportation access (land, sea, or air) for servicing or initiating a drilling operation may be required. Fuel consumption during water well drilling averages 1 gallon per foot and includes transportation to the site.

3. Permits and Regulations

A water rights permit may be issued by the State, but no State permit exists for water well drilling. Individual municipalities may issue construction regulations and require permits.

4. Description of Action and Equipment

Cable and rotary drilling may be used for water wells. The rotary system is more efficient, but is not economical when used for water. A description of the rotary drilling method is included in the discussion on oil and gas drilling.

Cable drilling is accomplished as a drill bit attached to a cable strikes the ground when the bit is lowered. Because of the elasticity of the cable, the drill bit turns a few degrees on the downstroke and returns to its original position with release of tension on the upstroke. This winding and unwinding action of the cable maintains the shape of the hole and allows the well casing to be driven efficiently.

An open hole can be drilled in bedrock, but in unconsolidated formations casing must be driven as drilling proceeds to prevent the hole from collapsing. The casing consists of high-quality steel with coupled or welded joints which allow no water seepage. The bottom of the casing is fitted with a heavy-walled steel drive shoe which serves as a cutting edge while the casing is being driven.

During the initial stages of drilling, water is pumped into the hole to form a slurry which cools the drill bit and allows the removal of drill cuttings. Once the well is in water-bearing strata, injection of water is no longer necessary. To extract the drill cuttings, the bit is raised and a sand pump is inserted to pump out the slurry, which is deposited in a pit beside the well.

There are no set rules or standards for a drilling operation. As the well is drilled, vibration may cause the walls to cave in. When the pressure on the casing becomes so great that it is impossible to drive it any further, a casing of a smaller diameter is inserted and drilling continues with a smaller bit. This may be done several times, depending on the depth of the well. When the well reaches the proper depth, a screen is inserted at the bottom and packed with gravel. Sand and silt are flushed from the screen, leaving only large pieces of gravel. The top of the hole is then cemented or grouted, and a pump is installed.

Wells vary in size from 6 inches in diameter for a single dwelling to 24 inches for a public utility. For a single-dwelling unit, a flow of 5 gpm is usually sufficient; for a public utility unit, 1500 to 2000 gpm is required. Well depths may range from 50 to 500 feet (for example, the average well in the Anchorage area is approximately 200 feet deep). Wells drilled in permafrost areas pose additional problems, since water freezes in the well. To prevent this, water can be circulated through the well and a heating element can be installed.

5. Impacts

a. Air Quality

The equipment used in drilling operations is usually powered by diesel fuel. The pollutants associated with this fuel combustion are carbon monoxide, nitrogen oxides, particulates, and sulfur oxides, as shown previously in Table IV-V. The overall output of pollutants is fairly small.

b. Noise

Noise levels associated with drilling are dependent on two primary factors: the type of equipment used and the geologic type of material being drilled. Rock drills are generally pneumatically powered, but there are also hydraulic and electric models. The dominant sources of noise in the hydraulic tools are the high-pressure exhaust and the

impact of the tool bit against the material. Noise levels at 50 feet typically range from 80 to 97 dBA. An exhaust muffler on the compressed air exhaust can lower noise levels from the exhaust by up to 10 dBA.

Once the well is drilled, stationary pumps are employed which generally run continuously at a relatively constant power and speed. Pumps produce noise levels ranging from about 65 to 73 dBA at 50 feet. However, because pumps operate continuously at a fixed location, engine mufflers and enclosures can be used to reduce these levels by about 10 dBA. In cases where use of electrically powered pumps is feasible, the noise levels generated at 3 feet range from 45 dBA to 93 dBA, depending on the size and operating mode of the equipment.

c. Water Resources

Uncontrolled disposal of the slurry used in the initial stages of drilling and silt flushings from the completed well may cause local increases in the turbidity of receiving waters, resulting in the effects discussed in Section II.C.1, Turbidity. In remote locations where access and community facilities are required, the impacts may be similar to those of a community development.

d. Terrestrial Biology

Barring any unforeseen complications such as subsidence and an extensive drop in the water table, drilling for water may be expected to exhibit minimal detrimental impacts on terrestrial plants and animals. On the drilling site, some destruction of plants and animals will occur. The effects of the removal of vegetation and the extirpation of some animals are discussed in Section II.D.2. Deposition of slurry from the operation will also destroy some vegetation and additional animal species. In the surrounding area, compaction and air pollution of heavy drilling equipment will also be injurious to the local flora and fauna. Perhaps the greatest impact will result from noise and human activity on the site, causing mobile animals to emigrate from the area and other that normally would use the site for food, shelter, or a migration route to avoid the area. In remote locations, where equipment and camp facilities are constructed, human pollution and harassment may be an important factor that will exhibit detrimental impacts to sensitive wildlife species.

e. Aquatic Biology

Drilling for water for a single well does not normally affect the aquatic environment. However, activities conducted during rainstorms or without proper erosion control could result in the impacts discussed in Section II.E.1. In remote locations, where access and community facilities are required, impacts may be similar to those for a community development.

f. Soils

Those impacts identified with clearing and grubbing are also applicable to water drilling. However, the extent of vegetation removal is generally small. An additional impact associated with water drilling is subsidence. Subsidence caused by the withdrawal of groundwater has been documented in several areas in California, Texas, and Mexico. Subsidence as great as 25 feet has been recorded in these areas, though generally subsidence is much less. Subsidence has occurred where the hydrostatic pressure (artesian pressure) within a confined aquifer was substantially reduced by heavy withdrawal of water (Polard and Davis, 1971). One can expect subsidence to occur under similar conditions, particularly when the aquifer is overlain by loosely consolidated clayey sediments of the tertiary and quaternary age. Those sediments of volcanic provinces that contain montmorillonite as the dominant clayey material are particularly prone to subsidence (Polard and Davis, 1971). Subsidence can result in altered surface drainage and in damage to man-made structures.

g. Interactions

Deleterious impacts associated with water drilling are limited. Those considered important are as follows:

(1) Subsidence — Subsidence in land surface due to intensive groundwater withdrawal has been documented in several areas, including California, Texas, and Mexico (Polard and Davis, 1972). Reduction in hydrostatic pressure within a contained aquifer due to water drilling results in an increased grain-to-grain load on sediments. The sediments compact in response to the added load and subsidence may follow. Damage due to subsidence includes flooding in coastal areas; failures in water drainage within canals, drains, and sewers; and structural failure in buildings, pipelines, railroads, and other engineering structures.

(2) Lowering of Water Table — If water is withdrawn at a faster rate than the groundwater reservoir is being recharged, the water table will drop. A drop in the water table may reduce low flows of local streams, affect springs, and cause some shallow wells to go dry. Extended withdrawal without adequate recharge will deplete the groundwater reservoir. In development areas, the problem is further aggravated by the placing of impervious surfaces over the aquifer recharge area.

IMPACT ANALYSIS, DRILLING FOR WATER

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-30 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-30 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-48 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-49 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL				1,2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2	3			
	CU				1,2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2,3				
	SM				1,2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2,3				
B. NORTHWEST	CL				1,2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2	3			
	CU				1,2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2,3				
	IL	1			2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2,3				
	IU		1		2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2,3				
	SM				1,2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e	5	2,3				
C. UPPER YUKON/ PORCUPINE	IL	1			2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e		5	2,3			
	IU			1	2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e		5	2,3			
	SM				1,2,3,4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e			2,3,5			
D. TANANA	IL	1 2,a,c,d	2b 3	4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			5			
	IU		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
E. YUKON/KOYUKUK	IL	1		2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e		5	2,3			
	IU		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
F. YUKON/ KUSKOKWIM DELTA	CL			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	CU			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
G. UPPER KUSKOKWIM	IL	1		2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e		5	2,3			
	IU		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
H. COOK INLET	CL	1 2,a,c,d	2b 3	4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	CU		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	IL	1		2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	IU		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
I. COPPER RIVER	IL	1		2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e		5	2,3			
	IU		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
J. ALEUTIAN	CL			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	CU			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
K. BRISTOL BAY	CL		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	CU			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
L. KODIAK/SHELIKOF	CU		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
M. GULF OF ALASKA	CU/ CU			1,2,3	4,5,6	1b	3a,b,d				1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM		1	2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
N. SOUTHEAST	CL		1,3	2,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	CU		1,2,3	4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			
	SM			1,2,3,4,5,6	1b	3a,b,d					1			1 2,k;6			1a,b,c,d,e			2,3,5			

H. EXPLORATION FOR OIL AND GAS

1. Introduction

Exploration for oil and gas is the first step in recovering, processing, and marketing the finished petroleum products. Exploration, which is the basic action considered in this report, differs from recovery in that it is generally a less intense effort spread over many sites, usually covering large areas. Thus, while exploration may cover an area of thousands of square miles, actual production of the minerals may only occur at a few localized sites. Exploration techniques may only indicate the presence of oil or gas, or suggest quantities. Recovery operations require consideration of numerous major development activities and are scheduled if commercial quantities are available to establish production of the oil or gas. Recovery and development of oil and gas are not analyzed in this report and would require an in-depth analysis should such actions occur.

2. Resources Required to Complete the Action

During exploration, temporary camp facilities are required to protect, store, and maintain equipment and fuel. Housing must be constructed to shelter work parties. In permafrost areas, gravel is necessary to support activities and maintain soil stability. Drilling methods require drilling mud and water to wash crushed rock from the well.

3. Permits and Regulations

The permits and regulations required for the development of mineral resources are outlined in the Alaska Administrative Code, Title 2, Part 3. In addition, the State Division of Lands requires an operation and well casing plan.

4. Description of Action and Equipment

Initial exploration may utilize geochemical or geophysical techniques to determine the presence of petroleum deposits. The soil-gas method is the best known geochemical technique for oil explorations in the United States. Soil samples are gathered at intervals over the study area and are analyzed for differences in hydrocarbon content. The results are plotted on a map, which then may indicate the location of the source of oil or gas. The most useful geophysical technique employs shock waves and is known as reflection seismography. A shock wave is generated by exploding dynamite beneath the earth's surface or by dropping heavy weights on the ground (vibroiseis). The shock waves travel through the earth and return to the surface after reflection from the subsurface features. Seismic techniques are expensive and are used only for detailed analysis in areas which have been explored with other methods. Recent seismic exploration on the North Slope (1975) utilized detonations spaced at quarter-mile intervals.

Following geophysical and geological exploration, the next phase of activity is selection of a test site for exploratory drilling. A base camp may be established in remote areas or in local communities to support the activities of remote camps conducting the drilling operations. The base camp is typically on a 3-acre site, requires a runway for aircraft, and is staffed by approximately 50 people. A remote camp is typically established on a half-acre gravel pad for equipment and support facilities for approximately 20 people.

Rotary drilling is the most common method of drilling and uses a column composed of sections of pipe screwed together (a drilling string) and suspended from a derrick by a cable. A drill bit is screwed to the bottom pipe and the string is lowered, forcing the bit to penetrate the rock as it turns. A stream of liquid, generally colloidal mud, is pumped through the drill pipe to wash away the rock cuttings and bring them to the surface. Coring and other tests are conducted to evaluate the oil-producing potential of the geologic formation.

The recovery of large commercial quantities of oil and gas, such as at Prudhoe Bay, requires specific well construction to prevent caving and to protect the hydrocarbons from any contamination. Each well and mode of transporting oil and gas are site or region specific. The well head site would require the construction of semi-permanent facilities to protect equipment and house personnel, and would include gathering lines, long-distance large-diameter pipelines, and pumping stations. A pipeline system is the common mode of transporting either oil or gas quantities in Alaska. A pipeline system would require gathering lines, pump stations, camp sites for use during construction, airfields for use during both construction and operation of the pipeline, a communication system, lateral access roads, and material sites for construction materials. Prior to construction and placement of any pipeline system, roadways are required for access and the movement of equipment, materials, and personnel during pipeline construction activities. As previously stated, the development and recovery of oil and gas and its transportation requirements are dependent upon more parameters (e.g., routing, economics) than are discussed within the scope of this action. Hence, each developed field should be the subject of an in-depth study and would require site-specific evaluation for both recovery and movement. For further discussion of development activities, refer to Sections IV.N (Community Development) and IV.P (Natural Resource Development Complex).

5. Impacts

a. Air Quality

The exploration and recovery of oil and gas involve impacts associated with most of the basic engineering actions previously discussed, but also include impacts associated with the development of roads and, to a limited extent, community development.

The air quality impacts are discussed here in general terms under four categories: seismic exploration, transportation, base camps, and operation considerations.

The use of explosives in seismic studies involves the ejection of particulates (or water in underwater exploration) into the atmosphere. In general, most of the larger particles fall out in the immediate area, but the smaller particles may be carried some distance before they are removed or sufficiently dispersed by the atmosphere.

Transportation-related sources include the construction of roads and airports and the movement of vehicles, including helicopters and airplanes as well as ground or marine traffic, to bring people and materials to the sites. The impacts of these actions are better discussed in the section on roads. Construction activities generate dust which may be controlled by appropriate wetting techniques. The fuel burned in internal combustion engines results in the emission of pollutants to the atmosphere. Table IV-V summarizes emissions factors for heavy-duty diesel-powered equipment. Table IV-X summarizes emissions factors for the landing and takeoff cycles of different types of aircraft. Gravel roads are inevitably dusty, but standard control measures can be used at critical locations. Many areas of Alaska have the requisite atmospheric conditions for the formation of ice fog. Most airports and roads associated with this kind of engineering action have very light traffic, but each vehicle itself is a potential ice fog generator. Where these are located close to other facilities such as pump stations, base camps, or production sites, the problems may be more significant.

Base camps are a smaller version of what is discussed in community development. The essential elements include construction activities (as discussed in the basic engineering actions), vehicular traffic, power generation, heating of dwellings, and refuse disposal or incineration. These last three involve the combustion of material which is most often fossil fuels. Tables IV-XI and IV-XII give typical emissions factors for incineration and industrial and commercial heating. The actual amounts of emission will depend on the size of the operation and the temperatures and hours of darkness on the site.

Operation of oil and gas wells requires a series of facilities, all of which involve pollution. Some of these facilities include the oil fields themselves or platforms, pipelines, pump stations, transfer terminals, and refineries. Each of these facilities involves evaporative losses of hydrocarbons from valves, seals and tanks, heat and power generation, incineration of wastes, and emissions from upset conditions.

During the installation of these facilities, dust, exhaust, and crankcase emissions from diesel and gasoline engines would be coincident with construction activities. Emissions and dust are controllable to accepted standards, the former by mechanical means, the latter by wetting down the working area with water. The impact would be only during the time of construction and would end at completion of the activity.

TABLE IV-X. EMISSION FACTORS PER AIRCRAFT LANDING/TAKEOFF CYCLE

Aircraft	Solid Particulates (pounds)	Sulfur Oxides (pounds)	Carbon Monoxide (pounds)	Hydrocarbons (pounds)	Nitrogen Oxides (NO _x as NO ₂) (pounds)
Jumbo jet	1.30	1.82	46.8	12.2	21.4
Long-range jet	1.21	1.56	47.4	41.2	7.9
Medium-range jet	0.41	1.01	17.0	4.9	10.2
Air carrier turboprop	1.1	0.40	6.6	2.9	2.5
Business jet	0.11	0.37	15.8	3.6	1.6
General aviation turboprop	0.20	0.18	3.1	1.1	1.2
General aviation piston	0.02	0.014	12.2	0.40	0.047
Piston transport	0.56	0.28	304.0	40.7	0.40
Helicopter	0.25	0.18	5.7	0.52	0.57
Military transport	1.1	0.41	5.7	2.7	2.2
Military jet	0.31	0.76	15.1	9.93	3.29
Military piston	0.28	0.14	152.0	20.4	0.20

Source: U.S. Environmental Protection Agency, 1973

TABLE IV-XI. EMISSION FACTORS FOR
REFUSE INCINERATORS WITHOUT CONTROLS
(pounds/ton)

	Municipal	Industrial/ Commercial	Flue-Fed	Domestic*
Particulates	14 – 30	7 – 15	6 – 30	7 – 35
Sulfur oxides	2.5	2.5	0.5	0.5
Carbon monoxide	35.0	10 – 20	10 – 20	neg 300
Hydrocarbons	1.5	3 – 15	3 – 15	2 – 100
Nitrogen oxides	3.0	3.0	3 – 10	1 – 2

* Lower values are for incinerator with primary burner

Source: U.S. Environmental Protection Agency, 1975

TABLE IV-XII. COMPARISON OF EMITTED POLLUTANTS FOR
DIFFERENT FUELS FOR INDUSTRIAL AND COMMERCIAL HEATING
(in pounds/10⁶ Btu)

	Bituminous Coal ¹	Residual Fuel Oil ²	Distillate Fuel Oil ³	Natural Gas ⁴
Particulates	0.52 x % ash	0.15	0.11	0.01
Sulfur dioxide	1.52 x % sulfur	1.05 x % sulfur	1.01 x % sulfur	0.001
Carbon monoxide	0.08	0.03	0.03	0.02
Hydrocarbons	0.04	0.02	0.02	0.01
Nitrogen oxides ⁵	0.60	0.53	0.57	0.11

¹ 10 to 100 million Btu/hour size spreader stoker, assuming Btu content of 25×10^6 Btu/ton

² Assumes heat content of 6.3×10^6 Btu/barrel

³ Assumes heat content of 5.9×10^6 Btu/barrel

⁴ Assumes heat content of 1050 Btu/foot³

⁵ Horizontally fixed units

Source: U.S. Environmental Protection Agency, 1975

In many cases, new industrial heaters and boilers would come under new source performance review and would have to meet those emissions restrictions, as well as the ambient air quality standards and nondegradation requirements. Vapor recovery systems will be required for many of the storage tanks. Emissions of sulfur dioxide are of particular concern because of their effect on lichens at concentration levels down to 0.05 ppm (0.14 ppm is the 24-hour primary standard for sulfur dioxide). In regions where caribou forage on these lichens, natural gas may have to be considered as the fuel to be burned to keep ground level concentrations low.

Ice fog may sometimes occur at larger facilities in interior Alaska, but its effects outside the station compound would be small. An oil well blowout which results in a fire would normally contribute a considerable amount of pollutants to the air. This is generally considered an emergency situation and is not covered by appropriate standards.

b. Noise

Exploration and recovery of petroleum minerals have a variety of associated noise problems. Reflection seismography could result in a short-term impact of significant magnitude. Due to the fact that the explosion is detonated underground or under water, the resulting vibration rather than the airborne noise may create the most harmful effects. Alpin (1947) reported that underwater explosions for seismic exploration kill some fish that have air bladders, especially if they are subjected to a broadside pressure wave. Fitch and Young (1948) also reported fish kills while using explosives for seismic exploration. Deaths were primarily due to rupture of the air bladders of these fish. On three occasions such explosions killed California sea lions and diving birds (Fitch and Young, 1948).

Shock vibrations are also known to have detrimental effects upon the embryological development of fish eggs. All salmonid eggs pass through a vibration-sensitive period just after egg fertilization which lasts 30 to 40 days (Olson, 1974). Shock waves originating on land and transported to adjacent water bodies could cause the loss of fertilized eggs during this vibration-sensitive period.

The startle response of birds and terrestrial mammals to blasting is frequently reported. With respect to bird populations, nest desertion of some species often results in increased predation (Shaw, 1970; Graham, 1969; MacInnes and Mishra, 1972; Gallop, et al, 1974). The short- and long-term effects of such disturbances on ecological balance are still poorly understood; however, studies are currently in progress that may add valuable insight on these effects.

Other noise-producing activities associated with this action include exploratory drilling and pumping, and transport of material and labor. The noise levels expected from these actions are more fully described in previous sections. (See Clearing and

Grubbing, Surface Excavation, and Drilling for Water.) Truck and aircraft transportation of material and labor must also be considered. Heavy-duty diesel trucks create noise levels ranging from a mean of 78 to 92 dBA at a distance of 50 feet. The overall impact of this noise source is dependent on the number of vehicles over time using these access roads. The federal government has responded to this as well as other noise sources through the Noise Control Act of 1972 (86 Stat. 1234 Public Law 92-475). Pursuant to the authority contained in Section 18 of this law, the Environmental Protection Agency has proposed rules for transportation equipment noise emissions for medium- and heavy-duty trucks (40 CFR 205). The standards for vehicles in the category expected to operate at this type of site, measured at 50 feet from the centerline of travel, are 86 dBA at speeds of 35 mph or less and 90 dBA at over 35 mph. To determine the statistical distribution of noise over time, worst-case, 1-hour volumes are required to model the expected roadway noise.

As described in the aircraft noise model, the noise exposure forecast (NEF) for aircraft operations at a given point is composed of the effective perceived noise levels (EPNL's) produced by each aircraft class over a 24-hour time period. The effect of aircraft and helicopter noise harrassment on human populations is discussed in Section II.B.1.

The effect of aircraft noise on wildlife has been poorly documented. However, Schwunburg (1974) found that waterfowl vary in their ability to adjust to aircraft disturbance. In marshes and bays, where there was greater protection, they seemed to better withstand sustained pressure. Gallop, et al (1974) reported that passerine birds are habitat-specific and will tolerate a degree of disturbance so long as the natural vegetation remains intact. However, it was further found that during breeding there were measurable detrimental effects on passerine reproductive success in disturbance areas. A study of coastal breeding birds showed that human presence was the most potent form of disturbance affecting the normal incubating behavior of all species studied (Gallop, et al, 1974a). It was further noted that aircraft disturbance affected the normal incubating behavior of black brant, glaucous gulls, and Arctic terns, but had little obvious effect on that of the common eiders. With respect to the effects of aircraft disturbance on molting sea ducks, it has been found that some species vacate traditional molting areas if subjected to human disturbance (Sterling and Dzubin, 1967). According to a study by Gallop, Goidsberry, and Davis (1974), passage of aircraft caused molting waterfowl to alter normal behavior and repeated exposure would have a detrimental effect.

Habituation to aircraft disturbance is thought to have occurred in several studies of ungulate populations, including reindeer (Thomson, 1972) and Dall sheep (Reynolds, 1974). McCourt and Horofman (1974) found the reaction of barren-ground caribou to aircraft varied with season and activity. The greatest reactivity was found to be during post-calving and in winter, and the least reactivity during fall migration and summer movement.

c. Water Resources

Geochemical exploration techniques have the potential for placing sediment material into suspension, which causes an increase in local turbidity. The effects are described in Section II.C.1, Turbidity. Exploratory drilling for either oil and gas or hard rock minerals requires support facilities in which water quality degradation is probable from the release of drilling mud and wash water into surface waters (Section II.C.1, Turbidity), spillage of fuels (Section II.C.2, Toxic or Deleterious Substances), and discharge of sanitary wastes into surface waters (Section II.C.7, Coliform Bacteria). Effects of borrow operations for gravel as fill material were described in Sections IV.B and C, Excavation and Construction Filling on Land.

d. Terrestrial Biology

The greatest impact from exploratory operations results from oil spillage at a successful but uncapped well. Spilled oil will cause detrimental effects in both terrestrial and aquatic habitats. Terrestrial oil spill studies at Barrow, Alaska (McCown, Benoit, and Murrmann, 1970) indicated that plants that had been physically covered by oil were dead after 60 days. This was especially noticeable on low-growing mosses and liverworts that had been covered at least 5 liters/m². Crude oil also reduced biomass and chlorophyll production. These authors further concluded that (1) on drier soils oil penetrated to the permafrost, whereas in wet sites characterized by a thick organic layer the oil did not penetrate below the vegetative level; (2) the organic mat, even when wet, had the capability of absorbing large quantities of oil; (3) damage to plants can be expected at soil hydrocarbon levels above 20 mg/g dry soil, and lethal levels of oil occur at approximately 40 mg oil/g dry soil; and (4) heavy oil treatment (12 liters/m²) produced, on the average, a two-fold increase in soil respiration. In general oil from seeps or spills is toxic to plants (phytotoxic) when it contacts the foliage.

Death of plants covered by oil in areas underlain by permafrost would result in permafrost melting and degradation. Severe erosion would then become a possibility on the spillage and surrounding site. Oil under pressure could spray for considerable distance, as reported by Rickard and Deneke (1971). These authors indicated that, during one spill from the Harnes-Fairbanks military pipeline, oil sprayed 100 feet in the air and saturated plants downwind for 100 to 200 feet.

To protect animals from coming in contact with oil-covered vegetation, cleanup operations must involve the removal of oil-soaked vegetation including the organic mat. Draining oil in temporary storage pits from which it may be pumped or shoveled is also a possibility. However, the removal of oil would destroy the vegetation and the habitat that the spill area normally provided for wildlife and destroy some wildlife habitat. Mud and other drilling wastes will undoubtedly also cover some vegetation. The influence of oil

spillage on aquatic communities is described under the aquatic biology and interactions sections for this action.

Detrimental impacts to terrestrial environments would also result from landscape changes, vegetation removal, and the effects of organic and inorganic pollutants produced by man and machinery. The specific and varied impacts from these three major outcomes are described in Section II.D. Dominant impacts are expected from localized destruction and pollution during construction and operation of the numerous exploratory sites that are necessary to establish the location of economically minable oil resources. Blasting and other equipment noise will affect animals, as discussed in Section IV.H.5.b, Noise. Harassment of animals, especially predators, may increase and predators considered especially threatening may be sought out and destroyed. Mammalian and avian predators are especially sensitive to human disturbance and may be expected to emigrate from regions of greatest and continual activity. In general, wildlife utilization of the area will be adversely affected by the increase in vehicular traffic, aircraft, machinery, and human activity.

e. Aquatic Biology

Impacts on aquatic biology are expected to vary, depending upon the exploratory technique used. Initial gravimetric and geochemical exploration could result in stream sedimentation, depending on sampling location and transportation to the site. Reflection seismography could affect aquatic life, as discussed in Section IV.H.5.b, Noise. Extensive exploration normally results in off-road travel, which could contribute to erosion and sedimentation.

Camps developed for exploratory work could be expected to generate impacts similar to, but less extensive than, those described in Section IV.N, Community Development. Additional sedimentation could result from the release of drilling and waste to surface waters.

f. Soils

Those impacts identified under Clearing and Grubbing, Foundation Construction, and Road Construction are also applicable to this action. Other impacts are discussed in the following paragraphs.

The action will result in removal and disturbance of vegetation and surface organic mat on the site and adjacent to the site by people and by heavy machinery. Erosion, sedimentation, subsidence, and mass wasting can result. The degree of damage to soils is dependent on the type of soil disturbed, the local geology, the climate, and the operational methods used, particularly revegetation and timing.

The action often entails moving heavy equipment over areas where roads do not exist. Disturbance of this type has been documented to cause potentially severe erosion in areas underlain by shallow permafrost of ice-rich fine- to medium-grained soils (Hok, 1969). Caterpillar-tracked overland vehicles have the most severe effect on these soils (Burt, 1970). Air-cushion vehicles minimize these adverse effects (Betchel, Inc., 1972). In addition, winter operation, when the ground is frozen, can also reduce potential impacts. Overland travel during thawed conditions or on steep slopes can aggravate these impacts.

g. Interactions

Major impacts associated with exploration and recovery of oil and gas on interactions are as follows:

(1) Subsidence — The removal of oil and gas from beneath the land surface can result in decreased hydrostatic pressure. Decreased hydrostatic pressure in confined systems, such as oil and gas zones, results in increased grain-to-grain load on sediments. The sediments compact in response to the added load and, consequently, the surface subsides (Polard and Davis, 1972). Damage caused by subsidence takes several forms. In coastal areas flooding can result. Changing gradients can have serious effects on the ability of canals, drains, and sewers to function properly and structural failures in buildings, pipelines, railroads, and other engineered structures have been documented (Polard and Davis, 1972).

Major subsidence problems of oil fields which have been documented include Goose Creek oil field in Texas; Wilmington oil field in the harbor area of Los Angeles and Long Beach, California; and oil fields on the shore of Lake Maracaibo in Venezuela (Polard and Davis, 1972). Many smaller such subsidence occurrences have been documented (Grant, 1944; Gilluly and Grant, 1949).

(2) Oil and Gas Spillage — Oil spills in areas of seasonal concentrations of migratory species, particularly waterfowl, can have deleterious effects on regional, statewide, and national populations. Water-associated birds that come into contact with crude oil lose the insulation ability of their feathers and frequently die of body heat loss and exposure. The combined effects of emulsifiers and crude oil are even more pronounced. Secondary toxic effects of the crude oil may also, in part, be responsible for mortalities. Key feeding areas (tide flat communities and eel grass communities) are prone to oil contamination that may render them unusable to dependent migratory species.

The most prevalent accidental organic contaminant on a worldwide basis is crude oil (Simmons, 1974). An estimated 1 billion gallons per year of crude oil are lost in transport due to collisions, transfer leaks, and explosions. An additional unknown quantity is lost through tank washing at sea and seepage from installations at transfer points (Simmons, 1974). Since the majority of crude oil is transported by sea, oceans are a major

receptor for this pollutant. Oil spills in marine environments contribute to the global aggregate of oil contamination of these environments. Little is known concerning the long-term cumulative effect of oil fractions which have a long residence time in sea water. Predictable adverse impacts are disruption of marine food chains, direct toxic effects (particularly on juvenile species), and sublethal effects. Some oil fractions do concentrate in food webs and are suspected carcinogenics. Small globs of resistant crude oil are often encountered by diving sea birds and can cause mortality.

The presence of oil can also interfere with the migratory behavior of anadromous fish by inhibiting homing and spawning behavior (Council of Environmental Quality, 1974). Many aquatic species utilize low concentrations of chemicals (a few parts per billion) as behavior signals for homing and reproduction. In some cases these chemical signals closely resemble high-boiling, saturated hydrocarbons. Some authorities believe oil contaminants can mimic natural stimuli, or saturate receptors, thereby interfering with the behavior of species (Blumer, 1969).

Many pesticides are soluble in oils and fats. Oil slicks and sediment oil have been documented to have pesticide concentrations 10,000 times greater than the surrounding environment (Hartung and Klinger, 1970; Vagners, 1972). If incorporated into food webs, their high concentrations of pesticides may be damaging to consumers near the apex of food webs.

IMPACT ANALYSIS, EXPLORATION FOR OIL AND GAS

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-35 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-35 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-45 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1	5,7	2,3	8	4a 6b	3	2a,c	
	CU	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1	2,3,4,7	5	8	4a 6b	3	2a,c	
	SM	1			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1	4	2,3,7	8		4a	2a,c 3	
B. NORTHWEST	CL	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1	5,7	2,3	8		3 4a;6b	2a,c	
	CU	1			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1	2,3,7		8	4a 6b	3	2a,c	
	IL	1	1	3	2,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1	7	2,3	5,8		3 4a	2a,c	
	IU	0																					
	SM	1			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1	4	2,3,7	8		4a	2a,c 3	
C. UPPER YUKON/ PORCUPINE	IL	2	1	3	2,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab 2c,d,e,h,j,k	1c 5b;6	2g 6,7	1	5	2,3,7	8	3 6b		2a,c 4a	
	IU	2		1	2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7	1	2,3,7	4	8		3 4a;6b	2a,c	
	SM	1			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c;3a 5b;6	2g 6,7		1		2,3,4,7	-8		4a	2a,c 3	
D. TANANA	IL	0																					
	IU	0																					
	SM	0																					
E. YUKON/KOYUKUK	IL	0																					
	IU	0																					
	SM	1			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c 5b;6	2g 6,7		1		2,3,4,7	8		4a	2a,c 3	
F. YUKON/ KUSKOKWIM DELTA	CL	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab 2c,d,e,h,j,k	1c 5b;6	2g 6,7	1	5,7	2,3	8	3 6b	4a	2a,c	
	CU	0																					
	SM	0																					
G. UPPER KUSKOKWIM	IL	0																					
	IU	0																					
	SM	0																					
H. COOK INLET	CL	2	1 2a,c,d;3	2b	4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab 2c,d,e,h,j,k	1c 5b;6	2g 6	1,7				2,3,5,7,8		3 6b	2a,c 4a
	CU	2		1,2	2,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab 2c,d,e,h,j,k	1c 5b;6	2g 6	1,7	4	2,3	7,8		4a	2a,c 3	
	IL	0																					
	IU	0																					
	SM	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c 5b;6	6,7	2g	1	4	2,3,4	8		4a	2a,c 3	
I. COPPER RIVER	IL	1	1	3	2,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	2g 6	1,7		2,3,7	5,8		3 6b	2a,c 4a		
	IU	0																					
	SM	0																					
J. ALEUTIAN	CL	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	7	2g 6	1			2,3,5,8		3 6b	2a,c 4a	
	CU	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	7,8	2g	1		2,3,7	8	3 6b	4a	2a,c	
	SM	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c 5b;6	6,7	2g	1		2,3,7	8	6b	3	2a,c 4a	
K. BRISTOL BAY	CL	2		1	2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	1;2g 6,7					2,3,5,8	3	6b	2a,c 4a	
	CU	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	1;2g 6,7				2,3,7	8		4a 6b	2a,c 3	
	SM	0																					
L. KODIAK/SHELIKOF	CU	2		1	2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	6,7	2g	1		2,3,7	8	6b	3	2a,c 4a	
	SM	1			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c 5b;6	6,7	2g	1		2,3,7	8	3 6b		2a,c 4a	
M. GULF OF ALASKA	CL/ CU	2		1	2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	6,7 2g	1			2,3,5,8		3 6b		2a,c 4a	
	SM	2		1	2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c 5b;6	6,7	2g	1		2,3,7	8	6b	3 4a	2a,c	
N. SOUTHEAST	CL	2		1	2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b		1ab;c;5b;6 2c,d,e,h,j,k	6,7 2g	1				2,3,5,8	3 6b		2a,c 4a	
	CU	0																					
	SM	2			1,2,3,4,5,6	1b 3a		3c,f			1;2b 6;7b	1ab 2c,d,e,h,j,k	1c 5b;6	6,7	2g			2,3,7	8	3 6b	4a	2a,c	

I. ROAD CONSTRUCTION

1. Introduction

The construction of roadways encompasses a variety of engineering activities including clearing, excavating, and filling. The extent to which these actions are involved is a function of the class of roadway and the terrain encountered throughout the course of the route. The purposes of roadway construction in Alaska do not vary significantly from those of the lower 48 states. Access to natural resources and between population centers and transportation terminals are all basic services which road networks provide.

2. Resources Required to Complete Action

Land easements for right-of-way corridors, suitable fill material, and roadway surface material are the primary resources required for roadway construction. Secondary resources include labor, equipment, fuel, and camp facilities. The State of Alaska Public Land Order requires a minimum 300-foot right-of-way for a primary highway. This involves a minimum of 36.3 acres per mile. The actual area of development and clearing will usually require approximately 12.1 acres per mile. Cleared areas for operations, crushing plants, batch plants, and construction camps are additional land requirements.

Labor requirements vary with the type and area of construction, but the short five-month construction period (May through September) increases the demand on this resource. Fuels are required for construction equipment, as well as for the transport of materials to the site. In more remote areas requiring work camps, additional fuel demands must be met. Approximately 90 percent of the fuel used is diesel; the other 10 percent is gasoline to power pickup trucks, small generators, and compressors.

3. Permits and Regulations

Table IV-XIII indicates the permits which may be required for road construction projects in Alaska. The application of specific permits and approvals is dependent upon the agency or individual sponsoring the construction, the type and location of the roadway, and the methods required to accomplish the action.

4. Description of Action and Equipment

Selection of a route, the first step in roadway planning and development, is based on a number of considerations in order to balance ecological, engineering, social, and cost criteria. Permafrost, a significant consideration in route selection, can be avoided by routing on south slopes and away from poorly drained low ground. Water bodies and natural drainage systems and other geologic barriers should be avoided if possible. Aerial

TABLE IV-XIII. ROADWAY CONSTRUCTION PERMITS

Permit	Legislation*	Issuing Agency	Application Purpose as Related to Roadways
Surface oiling	AAC Title 18, Chapter 75	Department of Environmental Conservation	The use of oil and petroleum products on state lands
Solid waste management	AAC Title 18, Chapter 60	Department of Environmental Conservation	Control of pollutant discharge from incin- erators burning solid waste generated by construction and discharge from temporary batch plants and generators (of 250 kilowatts or more) in construction yards and camps
Waste disposal	AAC Title 46, Chapter 3	Department of Environmental Conservation	Discharge of solid wastes from construction- related activities and camps into state waters
Pesticides	AAC Title 18, Chapter 90	Department of Environmental Conservation	Control of pesticides related to construction activities
Water rights application	AAC Title 11, Chapter 72	Division of Lands	For use of state waters in construction of roads or use in construction camps
Alteration of a water course or water body application	AS 16 AS 46.03 AS 46.15	Departments of Environmental Conservation, Fish and Game, and Natural Resources (Division of Lands)	Required for the relocation or alteration of a water body or water course
Material		Division of Lands	The use of state lands for such things as stockpiling and construction camps
Right-of-way		Division of Lands	For construction of improvements needing right-of-way on state lands
Airway/highway clearance		Federal Aviation Administration	For roads developed within a mile of airports
Environmental impact statement	National Environmental Policy Act	U.S. Environmental Protection Agency	For federal, state, and local projects involv- ing federal funding

AAC — Alaska Administrative Code
AS — Alaska Statute

photography and soil borings will identify foundation material opportunities and limitations. Route selection is also influenced by fill availability.

Every new highway involves a considerable amount of earthwork in its construction. The basic earthwork actions can be classified as clearing and grubbing, excavation (for roadway, borrow, and structural operations), filling to form embankments and slopes, and the finish grading and compacting actions. These actions were identified individually in earlier discussions.

Clearing is initiated during surveying, when the route centerline is established. Additional areas for staging and borrow sites will require clearing as well. An office plus two or three trailers and a rock crusher will also be located on the site. A bulldozer is the primary piece of machinery used in the majority of the clearing operation. Most vegetative debris is burned, and noncombustible debris is removed to a waste site and buried. Clearing, especially in areas of permafrost, should be minimized in order to maintain the vegetation's insulating effect on the active layer and to retard uncontrolled erosion.

Grading establishes a smooth well-drained roadbed on which to apply surfacing materials. Roadway construction requires excavation and disposal of undesirable and excess material. Filling must be accomplished where suitable foundation material is lacking or where elevations are not sufficient. Cut slopes through the undisturbed soils should ordinarily remain stable at 1:1; however, minimum 2:1 slopes should be maintained, and 3:1 are usually the rule when possible. Any solid rock encountered normally allows rock excavation as steep as a 1/4:1 slope. The primary equipment employed in excavation activities includes bulldozers, scrapers, loaders, and dump trucks.

Filling with sand and gravel mixed with clay and silt to provide a binding agent is the most desirable. An unbalanced cut and fill operation, where the quality or quantity of cut material is not adequate, requires borrowed material from other sites. The fill material is placed in relatively thin layers and compacted.

Roadway construction may also require bridge construction and drainage for stormwater runoff. The techniques employed attempt to minimize erosion and provide minimal obstruction to water flow and waterborne debris. Bridge construction requires the placement of rock and concrete abutments, foundations, pilings, and retaining walls. Drainage culverts are placed during subgrade operations.

Upon completion of the major earthwork, roadbeds, and structural features, action begins on the finish grading and compaction of the roadway. In many areas of Alaska, the surface is compacted and finished with a gravel surface. Otherwise, hot asphalt pavement mix is utilized as the final surface.

The revegetation of disturbed or altered rights-of-way is often required after roadway completion to stabilize the soil surface for erosion control. Roads constructed over permafrost and other unstable materials are developed with the intent of rebuilding damaged sections over a five- to ten-year period. Major damage and hazards receive immediate attention. A research proposal recently completed by the U.S. Army Cold Regions Research and Engineering Laboratories (1976) contains an extensive bibliography on environmental protection in relation to economic development of permafrost regions, including forecasting changes in geocryological conditions and restoration of damaged area.

5. Impacts

a. Air Quality

Road construction results in air quality degradation during three phases: construction, operation, and the secondary impacts associated with facilities to provide services to the persons using the road. In remote locations, these impacts should be small but, by the nature of roads, the end points and intersections with other roads may be cause for greater concern.

Construction results in stirring up of fugitive dust from clearing and grubbing; fill; excavation; transport of wastes, fill, and supplies; and rock crushing. There are also emissions from heavy-duty vehicles and, when camps are required, from power and heat generation and refuse disposal. These impacts are more completely discussed in the sections on basic engineering actions.

Use of the road will result in road dust, particularly from gravel-surfaced roads, and exhaust emissions from the vehicles. The quantity of fugitive dust emissions from an unpaved road per vehicle mile of travel may be estimated based on the speed of the vehicles traveling over the road, the silt content of the road surface material, and the mean number of days per year with more than 0.01 inch of rainfall. Approximately 60 percent of the particulates are less than 30 micrometers in diameter and may be suspended in the atmosphere indefinitely. Emissions from heavy- and light-duty vehicles are shown in Table IV-XIV for two ambient temperatures. There are several computer models available for predicting the impact of carbon monoxide emissions on the surrounding environment. Ice fog forming from the exhaust of motor vehicles may cause local visibility problems in areas where low winds and very cold temperatures prevail in winter.

The secondary impacts of road construction are often dismissed as unimportant or someone else's responsibility, but they can be important. Some of these impacts include service stations, restaurants, and other service facilities along the road; campsites and recreational development; and continuing repair, maintenance, and refuse disposal associated with keeping the road open and litter-free.

The potential for the development of an area's natural resources is greatly increased with the availability of an access road. Some of these actions are really like the establishment of communities, or at least permanent camps. Emissions involve pollutants from power and heat generation, transportation related to supplying these centers, and incineration of wastes. Campfires are the most significant source of pollutants at most recreational areas.

TABLE IV-XIV. EMISSIONS FROM HEAVY- AND LIGHT-DUTY VEHICLES FOR 1976 FOR TWO AMBIENT TEMPERATURES

	Model Year	Pollutant (grams/mile)			
		Carbon Monoxide 75°F	Carbon Monoxide 32°F	Hydrocarbons	NO _x
Light-duty vehicles	pre-1968	97.0	149.7	9.1	3.34
	1974	41.0	63.3	3.8	3.5
	1975	9.9	32.8	1.2	3.2
Light-duty trucks	pre-1968	125.0	192.5	17.0	4.2
	1974	47.2	72.7	4.4	4.8
	1975	28.5	94.5	3.0	4.6
Heavy-duty gasoline	pre-1970	238.0	*	35.4	6.8
	1974	169.0	*	13.3	12.6
	1975	168.0	*	13.2	12.6
Heavy-duty diesel	all	28.7	*	4.6	20.9
Motorcycles	all	30.6	†	8.1	0.2
Inboard vessels underway					
Steamship	all	0.91	†	90.8	2088
Motor	all	545.0	†	409.0	636

* Engines generally completely warmed up so emissions should be similar to amounts at higher temperature.

† Unknown

Source: U.S. Environmental Protection Agency, 1973

b. Noise

Road construction noise levels, as measured at 50 feet, are shown in Table IV-XV. These levels reflect various phases of activity associated with the construction program. Due to the shortened construction period in most of Alaska, roadway construction often extends over a longer work day. In populated areas this practice could interfere with normal sleeping activities, creating a more severe human impact.

TABLE IV-XV. CONSTRUCTION NOISE LEVELS FOR ROADWAYS*

Phase		All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site	
I	Clearing	84	84	Energy average, dBA
		8	8	Standard deviation
II	Excavation	88	78	Energy average, dBA
		7	3	Standard deviation
III	Compacting	88	88	Energy average, dBA
		8	8	Standard deviation
IV	Filling and paving	79	78	Energy average, dBA
		9	11	Standard deviation
V	Finish and cleanup	84	84	Energy average, dBA
		7	8	Standard deviation

* 50 dBA ambient

Source: Bolt, Beranek, and Newman, 1971a

The use of a roadway determines the long-term noise effects it will have on a community. For this reason, it is essential that expected noise levels be projected prior to construction, so that noise abatement measures can be incorporated in the planning stages. Types of noise abatement normally employed include

- Shifts in alignment and grade of roadway
- Acquisition of property rights for buffer zones or for installation of barriers along roadway

- Installation and construction of barriers
- Soundproofing of structures (not generally used)
- Use of quieter surfaces
- Use of quieter vehicles
- Noise zoning

Figures 4-1 and 4-2 show the noise plots of the L_{50} (noise level exceeded 50 percent of the time) for autos and trucks as a function of volume flow and average speed. The combined effects are then integrated in predicting the composite L_{50} and further adjustments are required to determine the L_{10} (level exceeded 10 percent of the time) or peak level. As described in Section II, the composite noise levels are used to determine the magnitude and extent of an impact, and thereby avoid future conflicts in land use.

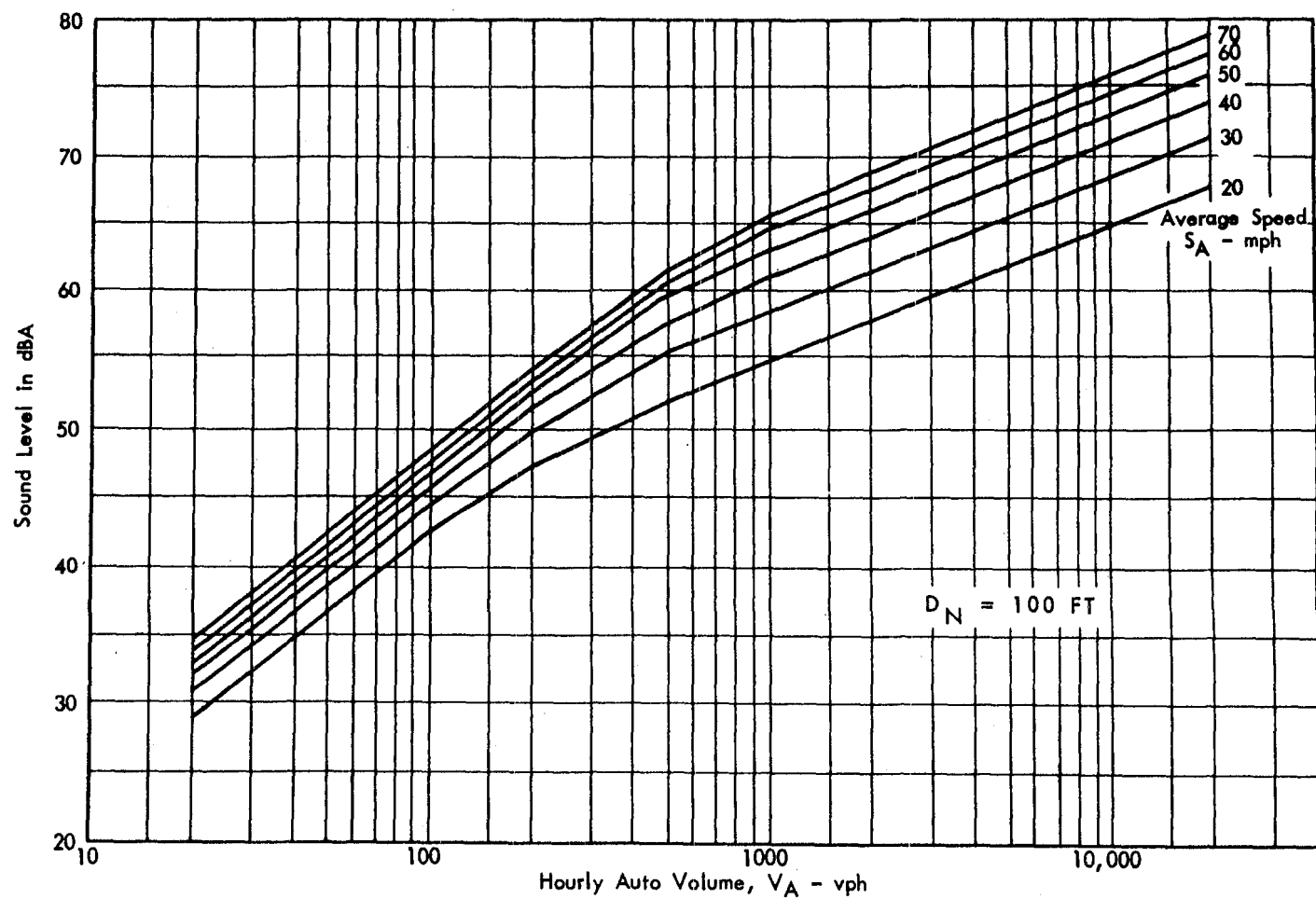
c. Water Resources

Road construction requires a considerable amount of earthwork: clearing and grubbing, borrowing, and placement of fill on land, in water, and in wetland areas. These operations clearly have the potential of causing short-term increases in the turbidity of surface waters. The effects of turbidity are described in Section II.C.1. The use of crushed rock as construction fill has the potential of releasing metal ions and their salts from freshly exposed surfaces in excess of natural occurring concentrations in surface waters. (See (Section II.C.2, Toxic or Deleterious Substances.)

Water quality degradation may also occur from the spillage of fuel oils during routine maintenance and construction activities (Section II.C.2, Toxic or Deleterious Substances), the discharge of organic matter and sanitary wastes into surface waters (Sections II.C.3, Dissolved Oxygen, and II.C.7, Coliform Bacteria) from the establishment of temporary construction camps. A secondary effect of road construction is entrainment of road oils, suspended solids, and toxic substances in stormwater runoff. The effects of these contaminants are discussed in detail in Sections II.C.1 and 2.

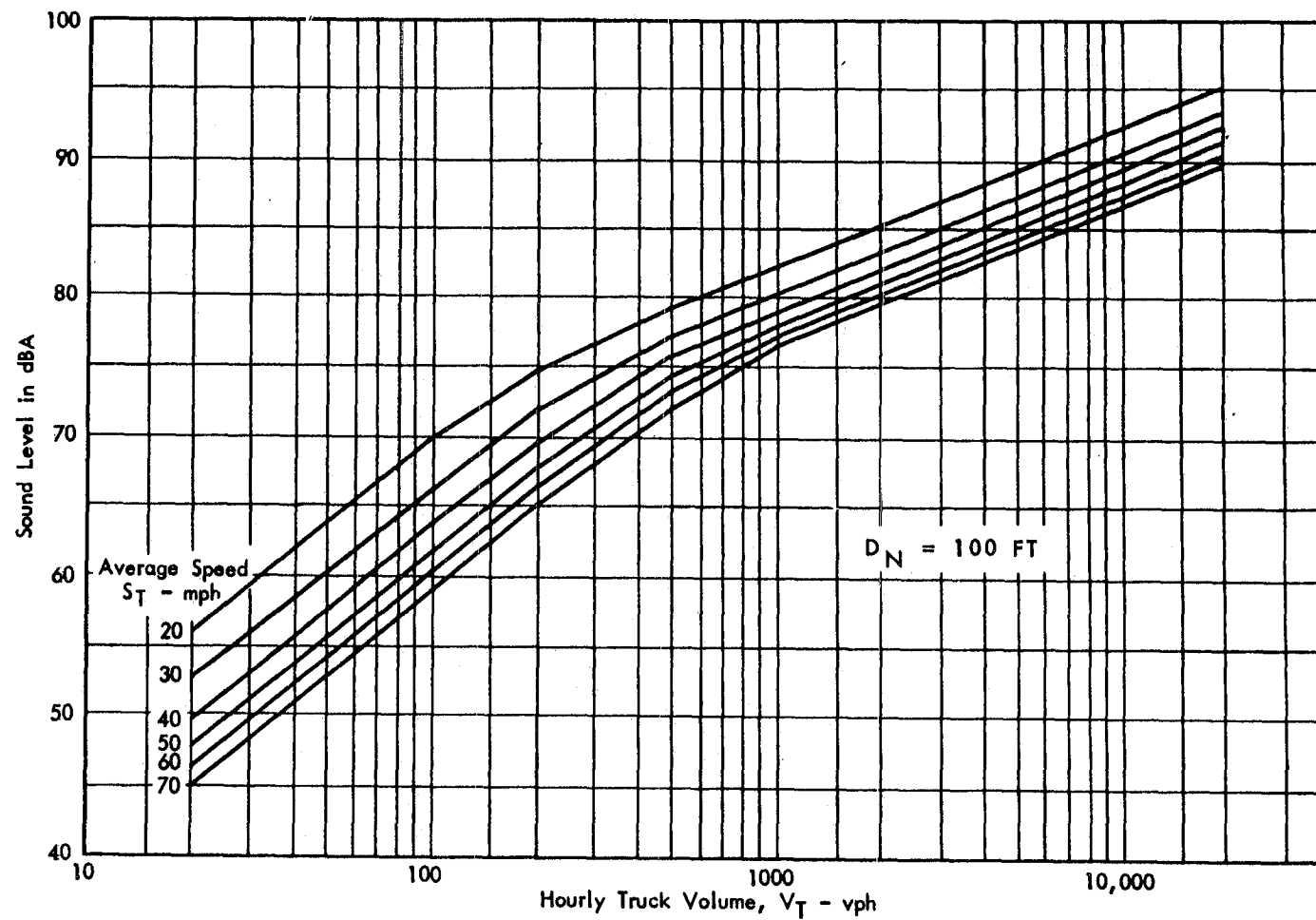
d. Terrestrial Biology

Road construction is damaging to vegetation and wildlife in many respects. The earthwork, including clearing and grubbing, borrowing, and the movement and distribution of soil from cuts and fills, will destroy vegetation and wildlife habitat and result in impacts as described in Sections II.D.1 and 2. Pollutants from heavy equipment and accidental spillage during construction will also destroy or alter vegetation, making it



Source: Gordon, et al, 1971

Figure 4-1. Plot of L_{50} for Automobiles as a Function of Volume Flow and Average Speed



Source: Gordon, et al, 1971

Figure 4-2. Plot of L_{50} for Trucks as a Function of Volume Flow and Average Speed

unsuitable for wildlife use. The influence of several specific construction pollutants on plants and animals is described in Section II.D.3.

Once the road is completed, vehicular traffic may either prevent or accelerate the distribution of plant and wildlife and may result in impacts also discussed in Section II.D.3. Additionally, grizzly and black bear, wolves, fox, moose, and other ungulates frequently migrate along road corridors. When these animals cross roads, they are more accessible to hunting pressure and prone to accidental death from motor vehicle/wildlife collisions. On the other hand, animals such as caribou may alter their migration routes in response to highway corridors (Klein, 1971) or may be limited in dispersal by them (e.g., small mammals). Heavy use of side roads, camp and picnic sites, restrooms, scenic turnouts, and other highway facilities will also lead to vegetation loss and habitat alteration. Roadside vegetation may be destroyed, leading to erosion and additional destruction of vegetation over many years. Sand, dust, and other particulates whipped up by natural wind or vehicular traffic may further damage vegetation and be harmful to animals that use the vegetation growing along the highways for food and/or shelter.

e. Aquatic Biology

Road construction may not directly affect the aquatic environment, but rainstorms or improper erosion control may result in the impacts discussed in Section II.E.1, Silt and Turbidity. The removal of gravel from streambeds for road preparation could also affect salmon populations, since loose gravel is necessary for spawning and normal egg development. Construction over water threatens aquatic life directly, and erosion and sedimentation must be minimized. Spawning, feeding, overwintering, or other critical areas may be destroyed during bridge or culvert construction. Migration patterns of anadromous species may also be altered if migration routes are obstructed.

The long-term effects of road construction are generally caused by the additional use of the area which the road generates. Stormwater runoff from highways conducts combustion pollutants, including hydrocarbons and heavy metals, to waterways where they may affect aquatic life, as described in Section II.E.2, Toxic Substances. Pesticides used to eliminate vegetation along roadsides also flow to stream courses (Section II.E.2, Toxic Substances). Increasing human activity along the transportation system usually results in increased nutrient contribution (Section II.E.6) and increases in sport fishing may require harvest limits to maintain existing populations.

f. Soils

Those impacts identified for clearing and grubbing, excavation, foundation construction, and construction filling on land also apply to road construction. Other impacts are discussed as follows:

(1) Erosion and Sedimentation — The effects of highway construction on erosion are summarized by Scheidt (1967).

The control of sediment resulting from soil erosion at highway construction sites causes considerable damage downstream, the correction of which requires careful application of the measures called for in the directive of the Bureau of Public Roads and the extension of similar measures to non-Federal highways and other construction through appropriate action by state, county, and other local government.

Although no data are available for Alaska, typical sediment generation for a divided highway which requires soil exposure of 10 to 35 acres per mile of road during construction is 3000 tons of sediment per mile (Wolman, 1964). In addition, once roads are built they alter runoff and drainage patterns, with subsequent effects on erosion and sedimentation. Roads add impervious surface to the landscape that increases volume of surface runoff. The increased volume of surface runoff represents a greater ability for the water to erode and move soils.

Drainage of highways on slopes can have serious erosional effects. Generally, water is collected from a hillside by a ditch which concentrates the flow and moves it parallel to the road, downhill. At some point, the water is moved across the road, usually by a subterranean culvert, and the water is then discharged. The greatest probability of washout and erosion occurs at the point of discharge.

(2) Mass Wasting — Alaska contains many areas of steep topography, permafrost, and geologic instability. These conditions make much of the state susceptible to mass wasting. Road construction initiates mass wasting by disturbing slope stability and altering drainage and loading through undercutting, and by concentrating surface and subsurface flows through ditching, bench-cutting, and filling. Such changes in drainage can supersaturate soils, increasing their weight and decreasing their cohesiveness. Obstruction of drainage or culverts will increase the potential for mass wasting.

Filling and paving can also increase the downslope load (weight) which can trigger mass wasting. Also, cutting of slopes reduces support for soils material upslope of the cut, again increasing the probability of slope collapse. Site specific soils, precipitation, shrink/swell properties, subsurface geology, slope, periodicity of freeze/thaw, and mitigating measures taken during road construction all combine to establish the danger of mass wasting at a specific site. Conditions of steep topography, heavy precipitation, unconsolidated soils underlain by an impervious layer, or soils with severe shrink/swell properties are particularly unstable. Seismic instability further magnifies the probability of severe mass wasting.

(3) Permafrost — In areas of permafrost, road construction can result in severe mass wasting and erosion. Effects of road construction on erosion were previously

described. In addition, impeding surface and/or subsurface water flows can result in permafrost degradation, as collected water has high specific heat and the ability to melt permafrost. If the area is drained, erosion is characteristic; if undrained, subsidence can be expected. Ice-rich fine-grained soils are particularly sensitive and unstable. If possible, these areas should be avoided. Other mitigating measures include the following:

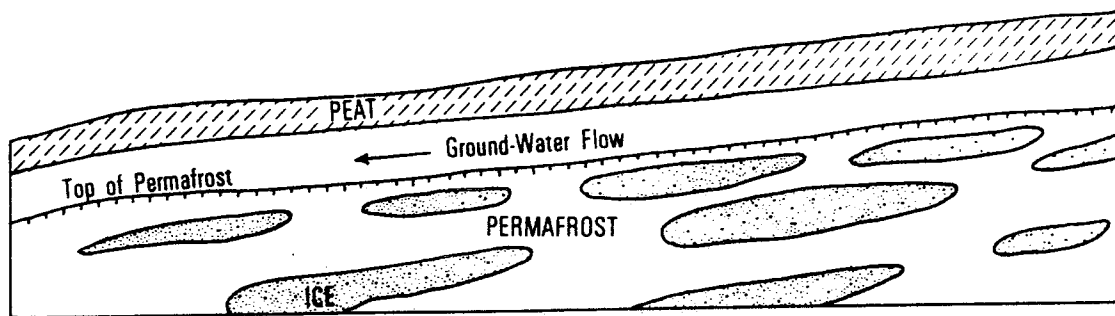
- Minimize disturbance of the vegetation and humus layer along the proposed roadway.
- Insulate permafrost by placing an adequate insulator between the roadway and permafrost (i.e., gravel, 2 to 5 feet, depending on the depth of the active layer).
- Design and maintain culvert systems so that drainage is not impeded.

In areas of discontinuous permafrost, complications are compounded by differential frost heave of roadbed soils, causing buckling. If frost heave conditions occur, possible mitigating measures include the following:

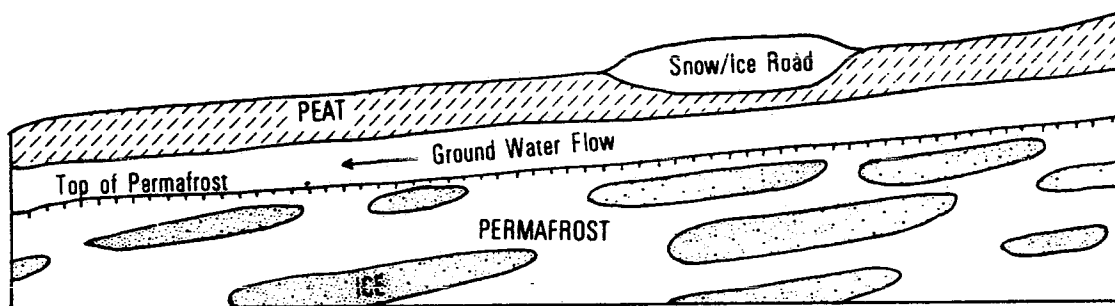
- Place routes on coarse soils on south-facing slopes.
- Remove and replace frost-susceptible soils from the roadbed.
- Add sodium or calcium chlorides to frost-susceptible soil layers.

Treatment may require repeating in an estimated five years, and probably is less effective in extremely cold climates.

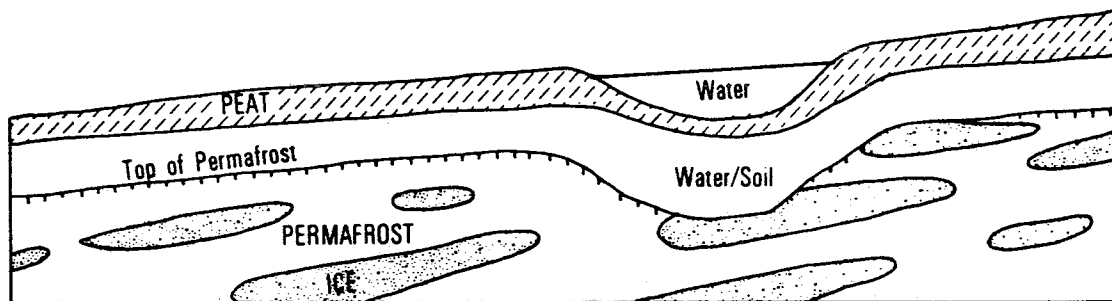
Subsidence in permafrost areas as a result of road construction is illustrated in Figure 4-3. Subsidence results due to changes in the thermal equilibrium by altering the insulating effects of surface humus and vegetation through removal or compaction. If the ice within the permafrost melts at a rate which is faster than the ability of the soil to discharge the water (which is characteristic of ice-rich fine-grained soils), the total soil mass can act like a liquid and move downhill on even moderate slopes of less than 3 degrees (U.S. Department of the Interior, 1975). Also, since permafrost is impervious and generally follows slope contours, subsurface drainage tends to collect at the base of the active layer where it acts as a lubricant, facilitating mass movement of the surface layer. During spring thaw, when surface soils are saturated, the problem is critical. Therefore, additional weight by loading or removal of support by undercutting can lead to mass wasting.



A. BEFORE CONSTRUCTION



B. IMMEDIATELY AFTER CONSTRUCTION



C. TEN OR MORE YEARS AFTER CONSTRUCTION

Source: U.S. Department of the Interior, 1975

Figure 4-3. Effects of Road Construction on Permafrost

(4) Subsidence — Effects of road construction on permafrost subsidence were previously discussed. Road construction over organic soils can lead to compaction of the soil and subsidence. Road construction on soils with shrink/swell properties, based on either moisture or temperature, will not cause subsidence, but will be affected by differential shrink/swell properties on adjacent soils. The effect will be manifested by buckling and heaving of the roadway.

(5) Compaction — The road system can lead to compaction of the soil beneath the road, which in turn can alter the permeability and drainage of the soil.

(6) Changes in Biological, Chemical, and Physical Properties of the Soil — Road construction and the presence of the road after construction lead to several changes in soil conditions. Soil pH can be altered immediately after surface pouring, due to leaching from poured concrete which creates alkaline conditions. Disintegration of concrete continues to develop alkaline soils and can substantially change the biotic community present (Milleret, 1963).

Road construction requires clearing and maintaining of a right-of-way somewhat wider than the road. In forested areas, such a maintained clearing can raise soil temperature, increasing microbial activity, humus breakdown, and nutrient release. If nutrients are not immediately taken up by invading vegetation, they can be lost to the soil system through leaching or runoff, resulting in a nutrient-deficient mineral soil. Fertilization may be required in order to maintain vigorous roadside vegetation. Planting of vegetation with nitrogen-fixing properties (e.g., legumes, alder, clover) can also restore the soil. Finally, roadways cover soils with an impervious layer which removes the roadway from biological production.

g. Interactions

Initial construction of roadways results in an increase in sediment transport to aquatic systems from terrestrial systems (Scheidt, 1971).

(1) Potential effects of increased sedimentation are a reduction in spawning habitat, alteration in makeup of benthic communities, increased turbidity, increased nutrient concentration, and increased oxygen demand.

(2) Some possibility of accidental spill of toxic substances, particularly petrochemical products, may occur. Through incomplete combustion and engine drip, small quantities can be expected to find their way to aquatic systems. Petroleum contaminants have both immediately lethal and chronically toxic effects on biota. Secondary effects are also deleterious (e.g., interference with gas exchange at water surface and matting of fur or feathers, with subsequent loss in insulation and/or buoyancy). Such risks are particularly

high due to hazards of highway accidents involving the spills of hazardous or toxic substances transported by truck (Scheidt, 1971).

(3) Heavily traveled roadways which cross traditional migration routes can impede normal migration patterns. Caribou are possibly most sensitive species to such disturbance, although other species may also be affected (e.g., brown/grizzly bear and moose). Disruption of traditional migration patterns can result in reduced carrying capacities and depredation of range, with subsequent reduction in population.

(4) Road access to areas previously difficult to reach will result in increased hunting and fishing pressure and increases in other disturbances caused by human presence. Of particular consequence is the extended range which such access provides to off-road vehicles (ORVs).

When misused, ORVs damage soil and destroy vegetation, disturb wildlife, destroy wildlife habitat, bring noise, litter, and vandalism to previously remote areas, and seriously disrupt other types of recreation. [Council on Environmental Quality, 1974]

(5) Road right-of-way maintenance often requires the periodic application of potentially toxic materials to melt ice and control roadside vegetation (e.g., salt and herbicides). These materials can adversely affect adjacent vegetation and wildlife and are easily transferred to aquatic systems where similar deleterious effects can result. The degree of impact would be a function of the type of material, quantities used, and timing and sensitivity of the area's ecology.

IMPACT ANALYSIS, ROAD CONSTRUCTION

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3	6	7	1a 2,c,e;6	1b,c;2,f,k 3a,b;7	2j 5c	1;2,d,f,g 3a		6	2,3,5,7,9	8		3;4a 6a,b		2a,c
	CU	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1,6	7	1a 2,c,e	1b,c;2,f,k 3a,b;6;7	2j 5c	2,d,f,g 3a	1	6	2,3,5,7,9	8		4a 6a,b	3	2a,c
	SM	1				1b 3a		1c 3b,c,e	2b 3	1,6	7	1a 2,c,e	1b,c;2,f,k 3a,b;6;7	2j 6c	2,d,f,g 3a;6	1		4	2,3,5,7,9		6a	4a	2a,c 3;5a,c
B. NORTHWEST	CL	2				1b 3a		1c 3b,c,e	1 2b,3	6	7	1a 2,c,e;6	1b,c;2,f,k 3a,b;7	2j 6c	1;2,d,f,g 3a		6	2,3,5,7,9	8		3 4a;6a	6b	2a,c
	CU	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3	6	7	1a 2,c,e	1b,c;2,f,k 3a,b;6;7	2j 5c	1;2,d,f,g 3a		6	2,3,4,5,7,9	8		4a 6a	3 6b	2a,c
	IL	1	1	3	2,4,5,6	1b 3a		1c 3b,c,e	1 2b,3	6	7	1a 2,c,e;6	1b,c;2,f,k 3a,b;7	2j 5c	1;2,d,f,g 3a		6	5,7,9	2,3,8		4a 6a	3	2a,c
	IU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3	6	7	1a 2,c,e	1b,c;2,f,k 3a,b;6;7	2j 5c	1;2,d,f,g 3a		6	2,3,4,5,7,9	8		4a 6a	3	2a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3	6	7	1a 2,c,e	1b,c;2,f,k 3a,b;6;7	2j 5c	1;2,d,f,g 3a		6	4	2,3,5,8		4a 6a	3	2a,c 5a,c
C. UPPER YUKON/ PORCUPINE	IL	2	1	3,4	2,5,6	1b 3a		1c 3b,c,e	2b 3	1,6	7	1a 2,c,e;6	1b,c 2,f,g	2j,k 3a,b;7	2,d,f,g 3a	1	6	5,7	2,3,8,9		3 6b		2a,c 4a
	IU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1,6	7	1a 2,c,e	1b,c 2,f,g;6	2j,k 3a,b;7	2,d,f,g 3a	1	6	2,3,4,7	5,8	9	4a 6a	3 6b	2a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1,6	7	1a 2,c,e	1b,c 2,f,g	2j,k 3a,b;6;7	2,d,f,g 3a	1	6	4	2,3,5,7,8,9		6a	4a 3	2a,c
D. TANANA	IL	1	1;2,a,c,d 3,4	2b	5,6	1b 3a		1c 3b,c,e	2b 3		1,6,7	1a 2,c,e;6	1b,c 2,f,g	2j,k 3a,b;7	2a	2,d,f,g 3a	1,6		8	2,3,5,7,9		3 6a	2a,c 4a
	IU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1	6,7	1a 2,c,e	1b,c 2,f,g	2j,k 3a,b;6;7	2a	1 2,d,f,g	6		2,3,4,7,8,9			3 4a;6a	2a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3		6,7	1a 2,c,e	1b,c 2,f,g	2j,k 3a,b;6;7	1 2,d,f,g;3a		6		2,3,4,5,7,8			3 6a	2a,c 4a
E. YUKON/KOYUKUK	IL	1	1	3,4	2,5,6	1b 3a		1c 3b,c,e	2b 3	1	6,7	1a 2,c,e;6	1b,c 2,f,g	2j,k 3a,b;7	2a	1 2,d,f,g;3a	1	6	2,3,4,7,8	9		3 4a;6a	2a,c 4a;6a
	IU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3		6,7	1a 2,c,e	1b,c 2,f,g;6	2j,k 3a,b;7	1 2,d,f,g;3a		2,3	4,7,8	9		3 4a;6a		2a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1	6,7	1a 2,c,e	1b,c 2,f,g;6	2j,k 3a,b;7	2,d,f,g 3a	1	6	9	2,3,7,8			3 4a;6b	2a,c
F. YUKON/ KUSKOKWIM DELTA	CL	2			1,2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3		6,7	1a 2,c,e	1b,c 2,f,g;6	2j,k 3a,b;7	1 2,d,f,g;3a		6	5,7,9	2,3,8		3 6b	4a	2a,c
	CU	0																					
	SM	0																					
G. UPPER KUSKOKWIM	IL	1	1	3,4	2,5,6	1b 3a		1c 3b,c,e	1 2b,3		6,7	1a 2,c,e;6	1b,c 2,f,g	2j,k 3a,b;7	1 2,d,f,g;3a		6		5,8,9	2,3,7		3	2a,c 4a
	IU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3		6,7	1a 2,c,e	1b,c 2,f,g	2j,k 3a,b;6;7	1 2,d,f,g;3a		6		2,3,4,5,8,9		4a	3 6a	2a,c 5a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b,3		6,7	1a 2,c,e	1b,c 2,f,g	2j,k 3a,b;6;7	1 2,d,f,g;3a		6		2,3,4,7,8			3 6a	2a,c 4a,c
H. COOK INLET	CL	1	1;2,a,c,d 3	2b	4,5,6	1b 3a	1c 3b,c,e		2b 3	1	6,7	1a 2,c,e	1b,c 2,f,g	2j,k 3a,b;7	2a	1 2,d,f,g	6		8	2,3,5,9	3	5a,c	2a,c 4a;6a
	CU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	3a	1 2,d,f,g	6		2,3,4,8	9	3 5a,c	4a	2a,c 6a
	IL	1	1	3	2,4,5,6	1b 3a		1c 3b,c,e	2b 3	1	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	3a	1 2,d,f,g	6		8	2,3,5,9	6a	3	2a,c 4a
	IU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	3a	1 2,d,f,g	6		2,3,4,8	9	6a	3 4a;5a,c	2a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3		1,6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	2 3a		1,6	4	2,3,8,9		5a,c 6a	3 4a	2a,c
I. COPPER RIVER	IL	1	1	3,4	2,5,6	1b 3a		1c 3b,c,e	2b 3		1,6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	2 3a		1,6	5,7	2,3,8,9		3	6a	2a,c 4a
	IU	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3		1,6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	2 3a		1,6	7	2,3,4,5,8		4a 5a,c;6a	3	2a,c
	SM	2			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3		1,6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	2 3a		1,6		2,3,4,8		6a	3 4a;5a,c	2a,c
J. ALEUTIAN	CL	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1,3	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7		1,2 3a	6		8	2,3,5,9	3 5a,c		2a,c 4a
	CU	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1,3	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7		1,2 3a	6		2,3,4,8,9		3 5a,c;6b	4a	2a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b 3	1,3	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7		1,2 3a	6	4	2,3,8,9		3;4a 5a,c;6b		2a,c
K. BRISTOL BAY	CL	2		1	2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b	3	6,7	1a 2,c,e	1b,c 2,f;6	2j,k 3a,b;7	1,2	3a	6		8	2,3,5,9	3	6a	2a,c 4a;5a,c
	CU	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b	3	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	1,2	3a	6	4	2,3,8	9		3 4a;6a	2a,c 5a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b	1,3	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	2	1 3a	6	4	2,3,8			3 6a	2a,c 5a,c
L. KODIAK/SHELIKOF	CU	2		1	2,3,4,5,6	1b 3a		1c 3b,c,e	2b	3	1,6,7	1a 2,c,e	1b,c 2,f		2	3a	1,6	4	2,3,8	9	5a,c 6b	3 4a	2a,c
	SM	0																					
M. GULF OF ALASKA	CU	2		1,2,3	4,5,6	1b 3a	1c 3b,c,e		1 2b		3,6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	1,2		3a 6	4	2,3,8	5,9	3;4a 5a,c;6b		2a,c
	SM	2		1,3	2,4,5,6	1b 3a		1c 3b,c,e	2b	1,3	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	2	1 3a	6	4	2,3,8	9	4a 5a,c;6b	3	2a,c
N. SOUTHEAST	CL	1		1	2,3,4,5,6	1b 3a		1c 3b,c,e	1 2b		3,6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	1,2		3a 6		8	2,3,5,9	3 5a,c;6b		2a,c
	CU	2		1,2,3	4,5,6	1b 3a	1c 3b,c,e		1 2b		3,6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	1,2		3a 6	4	2,3,8	9	4a 5a,c;6b	3	2a,c
	SM	1			1,2,3,4,5,6	1b 3a		1c 3b,c,e	2b	1,3	6,7	1a 2,c,e	1b,c 2,f	2j,k 3a,b;6;7	2	1 3a	6	4	2,3,8	9	4a 5a,c;6b	3	2a,c

J. DAM CONSTRUCTION

1. Introduction

Dams are normally constructed from concrete or earth and rock and serve to direct water from a river, raise the water level of a river for navigation, or store water for municipal and industrial use, irrigation, flood control, river regulation, recreation, or power production. Engineering activities include clearing the reservoir areas, construction of the dam, power facilities, roads, electrical distribution systems, recreation facilities, and employee accommodations.

Prior to construction, a site must be selected on the basis of hydrology, geology, topography, reservoir storage capacity, accessibility, land cost, and impacts on human, wildlife, and vegetative communities. The availability of suitable construction materials also must be considered. For a diversion dam, the site must be considered relative to the location and elevation of the outlet canal. Site selection for navigation dams involves factors such as desired navigable depth, channel dredging approach, and locations of other dams in the system.

Important topographic considerations include width of the floodplain, shape and height of valley walls, existence of natural spillways, and ability of the reservoir to retain impounded water. The controlling geologic conditions include the depth and engineering properties of soils and bedrock at the dam site, and the occurrence of sinks, faults, and major landslides at the dam site. The elevation of the groundwater table is also significant, because it will influence the construction operation and the suitability of borrow materials.

The method of constructing a dam depends on the topography, foundation conditions, and accessibility of construction materials and equipment. Generally, a hard rock foundation is most desirable because of its ability to support any type of dam, provided there is no danger of movement in existing faults and foundation underseepage can be controlled at a reasonable cost. Rock foundations of high quality are desired for arch-type dams. These dams are designed to distribute the full weight of the water to both the structure and canyon walls. An earth dam may be built on almost any kind of foundation, if proper design and construction techniques are used.

Availability of suitable construction materials frequently determines the most economical type of dam. A concrete dam requires adequate quantities of suitable gravel and reasonable availability of cement. The earth dam requires sufficient quantities of both pervious and impervious earth materials.

The height of the dam must provide temporary storage for flood waters exceeding the normal full pool elevation, as well as sufficient freeboard height above the maximum

surcharge elevation to assure an acceptable degree of safety against possible overtopping. The physical characteristics of the dam and reservoir site or the existing developments within the reservoir area may impose upper limits in selecting the normal full pool elevation.

2. Resources Required to Complete Action

An adequate river system is the first resource required to complete the action. Specific requirements include sufficient flow, a construction site for the dam, availability of construction materials (previously described), and compatibility with other uses of the river.

3. Permits and Regulations

Numerous federal and state permits and regulations are applicable. These permits and regulations are administered by the Federal Power Commission (Title 18 and Order Nos. 501 and 518) and the U.S. Corps of Engineers (Permits, Sections 10 and 404). State of Alaska regulatory agencies include the Department of Fish and Game (Anadromous Fish Act) and the Department of Environmental Conservation (water quality standards).

4. Description of Action and Equipment

Dam construction begins with the development of an access road between the dam site and the supply center for manpower, equipment, and materials. Construction camps are then built to provide temporary living quarters and maintenance and office facilities. Borrow areas are prepared and rock crushers, a batch plant, and sorting and stockpiling facilities are constructed. Clearing and grubbing operations for the dam foundation are then initiated and unsuitable material (consisting of vegetation, organic silt, ice, and other debris) is removed and disposed. Clearing activities are also required upstream from the dam in the area to be flooded. Additional roads and conveyor systems are constructed for material movement, as well as to provide access to excavation, disposal, and stockpile areas.

After clearing, grubbing, and excavation to the foundation level, a cutoff wall (consisting of sheet piling or other impervious material) is placed beneath the toe of the dam structure to restrict water seepage. The river is then diverted through tunnels or temporary coffer dams around the foundation construction site and back to the riverbed downstream from the site. The foundation is then constructed of concrete, rock, or earth fill with impervious cores or faces for erosion protection. During the placement of the foundation, outlet works such as spillways, tunnels, or penstocks are also constructed. Powerhouse facilities are constructed within or adjacent to the dam structure and require the construction of switch yards, transmission line corridors, and access roads.

Upon completion of the lower foundation walls and outlet works, flooding is initiated and the reservoir is filled to the design elevation. The reservoir may require several years to reach the full pool stage and limited operation may occur during this process. The depth, width, and upstream reach of the reservoir depend on the topography of the river basin and are factors considered in the design and construction of the structure.

Following completion of the dam, temporary construction camps are eliminated or replaced with limited permanent facilities as required for operation and maintenance procedures. Additional construction is generally limited to recreational developments or irrigation systems for agricultural or industrial purposes.

5. Impacts

a. Air Quality

The air quality impacts related to dam construction are associated with construction activities on the site; construction of roads, camps, and transmission corridors; and the operation of the dam once it is built. The construction activities on the site involve emissions to the atmosphere from clearing and grubbing activities that also involve burning debris. These emissions include particulates from open burning, fugitive dust, and some gaseous emissions from vehicles, which are discussed in Section IV.A, Clearing and Grubbing. Blasting during excavation also ejects particulates into the atmosphere.

The construction materials used for the dam itself may involve materials which must be extracted and transported to the site or on-site sand, gravel, or stone processing. Primary crushing operations may add 0.1 pound per ton of suspended particulates to the atmosphere, depending on the moisture content of the material. The use of moist sand and gravel may result in lower values. Secondary and tertiary crushing and screening result in emissions of 0.616 and 3.6 pounds per ton, respectively. Storage and movement of these materials also result in emissions. The quantity of suspended dust emissions from aggregate storage piles, per ton of aggregate placed in storage, may be estimated using the following empirical expression:

$$E = \frac{0.33}{(PE/100)^2}$$

where

E = Emission factor (pounds per ton placed in storage)

PE = Thornthwaite's precipitation/evaporation index

Particulate emissions during concrete batching operations consist primarily of cement dust, but some sand and aggregate gravel dust emissions also occur. There is also a potential for dust emissions during the unloading and conveying of concrete and aggregates at these plants and during the loading of dry-batched concrete mix. Another source of dust emissions is the traffic of heavy equipment over unpaved or dusty surfaces in and around the concrete batching plant. Control techniques include the enclosure of dumping and loading areas, the enclosure of conveyors and elevators, filters on storage bin vents, and the use of water sprays. Table IV-XVI presents emission factors for concrete batch plants.

TABLE IV-XVI. PARTICULATE EMISSION
FACTORS FOR CONCRETE BATCHING*
(EMISSION FACTOR RATING: C)

Concrete Batching	Emission	
	lb/yd ³ of concrete	kg/m ³ of concrete
Uncontrolled	0.2	0.12
Good control	0.02	0.012

* One cubic yard of concrete weighs 4000 pounds ($1 \text{ m}^3 = 2400 \text{ kg}$). The cement content varies with the type of concrete mixed, but 735 pounds of cement per yard (436 kg/m^3) may be used as a typical value.

Source: U.S. Environmental Protection Agency, 1973

Emissions may also occur during the construction of roads and transmission corridors, and during the supply, maintenance, and operation of construction camps. These effects are described in Section IV.I. Particulates from fugitive dust sources and open burning are the most significant, while gaseous emissions during fuel combustion from vehicles, power generation, and heating may be important locally. Emissions resulting from the operation of the dam are primarily gaseous as a result of fuel combustion where personnel are housed and from machinery associated with opening and closing the dam.

Most artificial lakes produced by dams have had negligible effects on the general climate, and even on the shower activity downwind from them. This has occurred because the lakes have been created in otherwise quite dry areas. The interaction of lakes in the coldest areas of Alaska in winter could result in fogging if there are open stretches of water. For a very large artificial lake, modifications in seasonal temperatures could be affected because of the heat capacity of water.

b. Noise

Noise impacts from construction and operation of a dam project are discussed separately due to the differences in the activities involved.

(1) Construction Noise — As in most types of construction, combinations of equipment are associated with various phases of activity. Table IV-XVII shows the typical noise levels, measured at 50 feet, which could be expected for such activities. In some cases, construction activities could extend over a period of years and would constitute a long-term impact. Noise levels of the type and duration expected would result in the disturbance of most wildlife species within the immediate area. Workers exposed to such levels are protected by the Occupation Safety and Health Act (OSHA) and in many cases would be expected to wear hearing protection devices during periods of exposure.

(2) Operation Noise — The primary sources of noise associated with operation and maintenance of dams consist of

- Power plant noise
- Transmission line noise
- Traffic along access roads
- Project-related maintenance activities
- Recreation activities

Power plant noise levels fluctuate, depending on the generator capacity; differences in terrain, vegetation, temperature, and wind; and presence of other extraneous noises. A great deal of common power plant equipment generates noise levels in excess of 90 dBA, unless noise abatement precautions are exercised. Presently, the noise control of each new electrical generating facility must be individually designed and evaluated because state noise pollution control regulations are not uniform, local community noise climates are unique, and equipment sound emission levels are variable.

Transmission line noise from high-voltage power lines may require special attention during the siting of the lines. Investigations have shown that the audible sound generated by electric power transmission lines increases when these lines are subjected to adverse environmental conditions such as fog, rain, or snow (Teplitzky, 1974). Transmission line noise emissions are characterized by discrete frequency tones corresponding to the even harmonics of the main frequency and broadband noise which is generated by a random sequence of electrical discharges in the air at the surface of the conductor, a phenomenon called "corona discharge." The tonal sound components are generated by the movement of space charges surrounding the conductor, which causes a reversal of the surrounding air pressure twice every half cycle. The relative sound level of the tones and broadband noise depends on factors such as voltage gradient, weather conditions,

TABLE IV-XVII. NOISE LEVELS ASSOCIATED WITH DAM CONSTRUCTION ACTIVITIES*

Phase	Type of Activity				
	Construction Camp	Public Works and Utilities	Dam Construction and Industrial Facilities	Roads and Trenches	
I Ground clearing	83	84	84	84	Energy average, dBA
	8	7	9	8	Standard deviation
II Excavation	88	89	89	88	Energy average, dBA
	8	6	6	7	Standard deviation
III Foundations	81	78	77	88	Energy average, dBA
	10	3	4	8	Standard deviation
IV Erection	81	87	84	79	Energy average, dBA
	10	6	9	9	Standard deviation
V Finishing	88	89	89	84	Energy average, dBA
	7	7	7	7	

* Assumes an ambient level of 50 dBA and all pertinent equipment present at site

Source: Bolt, Beranek, and Newman, 1971a

subconductor diameter, point of maximum gradient, and conductor surface conditions. Sound emission levels, as measured at 50 feet from the outer phase at midspan of a three-phase, 30.4-mm-diameter subconductor, EHV test facility are shown in Table IV-XVIII.

TABLE IV-XVIII. CLIMATE EFFECTS FOR A THREE-PHASE
FOUR-SUBCONDUCTOR BUNDLE TEST, 765-KV TRANSMISSION LINE

Weather Condition	Sound Level in dBA at 50 Feet		
	L ₉₀	L ₅₀	L ₁₀
Fair	36.5	40.0	44.0
Fog	36.5	51.5	58.5
Rain	54.0	57.5	59.0

Source: Teplitzky, 1974

Traffic noise is discussed in more detail in Section II.B, Noise, and Section IV.I, Road Construction. Opening of previously unused areas through construction of access roads generally stimulates their use for unrelated activities, thereby increasing human disturbance as well as traffic noises. Dam projects frequently become tourist attractions and recreation areas. In a study of traffic increases during periods of recreation area operation at one dam, traffic volumes were from 16 to 118 percent higher (John Graham, 1974). Corresponding noise level increases due to these volumes would range from 1 to 3.5 dB.

The use of dam reservoirs by power boat operators during summer months makes this a potential noise source. Power boat noise levels are influenced by engine noise, conducted noise radiating from the hull, and bow-wake splash. In addition, water and wind conditions, operating speed, and engine and boat size can influence the measured levels. The typical range of noise levels produced by pleasure boats is 64 to 98 dBA. In development of recreation areas which include boat launches, consideration should be given to potential noise problems. Maintenance of speed limits and prohibition of power boating in certain areas will serve to control intrusion of boat noise in noise-sensitive areas. Other recreation-related noise sources are discussed in Section IV.O, Recreational Development.

c. Water Resources

Construction operations can be expected to introduce suspended solids, including organic debris, into the water body. This will result in an increase in turbidity (Section II.C.1) and a reduction in the dissolved oxygen concentration of the water (Section II.C.3). Water quality degradation may also occur from the spillage of fuel oils during routine maintenance and construction activities (Section II.C.2) and the discharge of organic matter and sanitary wastes into surface water (Sections II.C.3 and II.C.7) from the establishment of a temporary construction camp. For a discussion of impacts due to change in flows upstream and downstream, refer to Section IV.J.5.g, Interactions.

The reservoir or lake created by the damming of a stream can be expected to alter the water quality regime in comparison to the original stream and will act as both a sink for upstream sources of water quality characteristics and a source for downstream water quality. As a sink, dissolved oxygen and temperatures can be expected to change seasonally and at the same time with depth. As a source, outflow from near the surface, at intermediate levels, or near the reservoir bottom can discharge water of a different temperature or turbidity than that of the normal downstream waters. Additionally, a reservoir acts as a sink for dissolved materials, enabling increases in concentrations of nutrients (Section II.C.6) such as nitrogen, phosphorous, and simple carbohydrates, both within the water and in bottom deposits. Potential consequences include increased productivity at the reservoir and decreased productivity downstream.

d. Terrestrial Biology

Dam construction may be described as several distinct engineering activities that occur chronologically over several years. Individually, and in combination, each activity exhibits a specific impact on the terrestrial ecology of the dam site and also on its surrounding watershed. The main activities, in their approximate chronological order, and ensuing impacts on the terrestrial biota include the following:

(1) Development of Access Roads and Conveyor Systems for Transporting Workers and Equipment to the Construction Site – The effects of road construction on plants and wildlife have been described in Section IV.I, Road Construction.

(2) Construction and Maintenance of Living Facilities for Construction Workers, Geologists, Engineers, and Other Personnel – The impacts of small and temporary camp communities on the biota of a site are clarified in Section IV.N, Community Development. However, the effects are short-term, differing only in the time frame of their existence.

(3) Preparation of Borrow Areas and Excavation of Rock, Gravel, and Other Raw Materials Required for Dam Construction — The general impacts of these actions on terrestrial communities have been discussed in Sections IV.B (Excavation), IV.C (Construction Filling on Land), and IV.D (Foundation Construction). However, effects are apt to be more severe because borrow areas may be extensive and the locations are likely to be in sensitive riparian habitats.

(4) Clearing and Grubbing at the Dam Site — In addition to a limited amount of clearing and grubbing that may occur upstream from the dam, clearing and grubbing at the dam site will affect terrestrial plant and animal communities, as described in Section IV.A, Clearing and Grubbing. Again, effects would be more severe due to the extent of the activities and their proximity to rivers.

(5) Construction of Accompanying Facilities Adjacent to the Dam — In most cases, facilities such as tunnels, powerhouses, and transmission corridors will require clearing and grubbing, excavation, some filling on land, and road and foundation construction. The influence each of these Level I or Level II activities has on plants and animals has previously been described. The amount and influence of powerhouse and transmission line noise, including its effect on wildlife, is described in Section IV.J.5.b, Noise.

Once constructed, power line corridors may influence the ecology of the region for many years. Upkeep for access usually requires the continual control of weeds, trees, and other colonizing vegetation. The most economical and frequently used method is to cut and remove large woody tree species and spray the remaining vegetation with herbicides such as 2-4-D, 2-4-5-T, 2-4-T, and dicamba. The aerial distribution of these nonselective herbicides approximately every five years destroys all vegetation (with the exception of "grasses") within the corridor.

Power line rights-of-way are frequently cut through large areas of uniform climax habitats and develop into early successional seral stages which provide vegetation that is heavily browsed by small mammal and ungulate species. High small mammal densities, however, attract populations of raptors who are sometimes killed from alighting on the hot line or flying into cables when diving for prey (Manwal and Bradley, University of Washington, personal communication). Distributional and genetic implications of power line corridors have been discussed in Section II.C.1.

(6) Flooding of Plant and Animal Habitat — Depending on location (specifically, width and topography), many acres of habitat may be inundated, thus destroying vegetation and wildlife. Frequently, critical wildlife winter range occurs in those low-elevation stream and lake habitats that will be flooded by damming. Dams, once constructed, may continue to influence plant and animal communities through secondary

effects. Large bodies of water behind the dam may influence the local microclimate of the region, which in turn may influence the distribution and abundance of plants and animals, especially in the vicinity of the waterline. The artificially controlled and often sudden water flows may be detrimental to wildlife, both below and above the dam site. Perhaps the most important impact of dams is their detrimental impact on anadromous fish species, as described in Aquatic Biology, below. The importance of a continuous and abundant supply of salmon to terrestrial animals, especially brown/grizzly bear, is well known and decreased salmon runs may substantially affect bear populations. Recreational use of lakes resulting from dam construction also may have detrimental impacts on wildlife and on vegetation near the lake.

e. Aquatic Biology

Short-term effects of dam construction occur as the river is diverted from its original course. Upstream migration of adult fish or downstream juvenile movement may be hindered, resulting in decreased spawning or successful development of young fish. The diversion will also result in additional erosion and stream sedimentation, with the effects discussed in Section II.E.1. Explosives detonated during construction may also affect aquatic life, as discussed in Section IV.H, Exploration for Oil and Gas.

The long-term effects of dam construction and operation may result in many changes in the aquatic system. Since the river is obstructed, upstream spawning migrations of salmon will be stopped unless facilities are provided which allow fish to bypass the dam and power-generating facilities. Even when fish ladders are provided, salmon runs decrease, since many fish become disoriented or refuse to use them. When downstream juvenile migration coincides with high water periods and water is spilled over the dam, gas bubble disease (as discussed in Section II.E.3.b) may cause extensive mortalities. Fish may also be harmed as they pass through the turbines in the power plant.

The creation of a reservoir upstream from the dam distinctly changes the characteristics of the aquatic environment. In general, the new habitat is not useful for some salmonid reproduction because the flow and dissolved oxygen are decreased, turbidity is increased, and critical spawning areas are deeply submerged. The temperature of the stored water also increases and the reservoir concentrates nutrients washed from the surrounding watershed.

The aquatic environment downstream from the dam also is affected by dam construction and operation. Downstream flows may be changed and salmon spawning areas may be destroyed. Irregular flows from the dam could also affect the timing of the downstream migration of juvenile salmon. In either case, the original environment is altered to such an extent that new aquatic communities may result which supplant existing species.

Reservoirs may establish favorable fish environments where none previously existed or create changes in initial aquatic characteristics that prove favorable to additional and/or different fish species. For example, a depauperate, shallow lake greatly influenced by climatic extremes conceivably may form the basis for a deeper, larger, benign and more productive reservoir which is able to support year-round fish populations. Similarly, aquatic environments which support silver, Chinook, and other anadromous fish, upon being changed to a reservoir, may support nonmigrating grayling, Arctic char, and lake and rainbow trout.

f. Soils

Those impacts described under Sections IV.A (Clearing and Grubbing), IV.D (Foundation Construction), and IV.I (Road Construction) are applicable to damming. Additional impacts are identified as follows.

(1) Mass Wasting — Higher water tables in the vicinity of reservoirs can decrease frictional resistance of material at the base of slopes and can increase the buoyancy of these materials, thereby initiating mass movement. This effect was in part responsible for the 1963 Vaiont Canyon slide which flooded the reservoir and resulted in the death of 3000 people (Bloom, 1969).

(2) Inundation — Inundation moves soils from terrestrial to aquatic systems, drastically altering their makeup. Characteristically, in reservoirs there is an initial pulse of nutrients released shortly after inundation, as flooded vegetation and humus is decomposed. After several years, the production in the reservoir is typically reduced.

g. Interactions

Impacts associated with dam construction on interactions are as follows:

(1) Dams upstream of estuaries modify historic patterns of freshwater river flow into estuaries. Typically, spring flows are reduced and summer flows increased. Total annual flows can be expected to decrease if consumption uses are established (i.e., community water supply, irrigation). The changing flow regime would alter physical circulation, nutrient availability, and biotic assemblages (Cronin, 1971).

(2) Dams physically block passage of anadromous fish attempting to migrate (Hynes, 1960; Mansueti, 1961) unless fishways are included. Even with fishways, reductions in quantities of adult fish successfully passing the barrier can be expected, and loss of juveniles through spillways and turbines can also be expected. Such barriers can eliminate important commercial, recreation, and subsistence species. The importance of anadromous fish to Alaska residents for commercial, recreation, and subsistence uses is extremely high, as is their importance to the Alaskan ecology.

(3) Spillways of dams mix atmospheric gases with water conditions of high pressure. The result is supersaturation of atmospheric gases (an increase in the amounts of dissolved gas) in the waters immediately below spillways. As fish breathe the supersaturated water, they incorporate large amounts of the dissolved gases. Under normal pressure and temperature conditions, the gases begin to leave the supersaturated state and form undissolved bubbles of gas, predominantly nitrogen. These bubbles, when released within the circulatory system or body cavities of fish, result in tissue damage and can result in death. Juveniles are particularly sensitive, and in the Columbia drainage have suffered mortalities as high as 70 percent on their downstream migration.

(4) Dams alter the nutrient output to marine receiving waters. In some areas such nutrient reductions have resulted in collapse of important fisheries (George, 1972). The effect of reduced nutrient transfer to Alaskan receiving waters is dependent on the makeup of the nutrient budgets in the area affected. At present nutrient budgets are largely unknown for most of Alaska's receiving waters.

(5) Dams commonly result in reduction of sediment drift downstream of the dam due to sediment capture within the dam basin. Consequently, river deltas in other parts of the world have undergone bank erosion due to the reduction of sediment impact from their respective rivers (Kassas, 1972) caused by dams. Also, erosional conditions in adjunct coastal areas can occur as rates of source material for littoral drift are reduced (Bascom, 1964).

(6) Dams can reduce the frequency and magnitude of floods downstream. Periodic flooding is necessary for the maintenance of extensive wetlands on floodplains and deltas, which are of critical importance to shorebirds and migratory waterfowl. Also, the reduction of silt-bearing floodwaters can result in loss of floodplain soil fertility. Seasonal and periodic flooding often replenish soils with nutrient-rich silts. The termination of replenishment may result in long-term losses in fertility of soils. In other parts of the world, increased use of fertilizers has become necessary to compensate loss of periodic enrichment of soils by floodwaters (Sterling, 1972).

(7) Flooding of river valleys by reservoirs could possibly interfere with normal migration patterns of caribou and inundate important wintering habitat for moose, feeding areas for grizzly bear, and breeding habitat for waterfowl.

IMPACT ANALYSIS, DAM CONSTRUCTION

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	0																					
	CU	0																					
	SM	0																					
B. NORTHWEST	CL	1			1,2,3,4,5,6	1b 3a,b,d			1,2b 3,5,8	6,7		1a,b 2c	2a,j,k	1c;2d 6	1;2d,e,f,g 3,5,7	8		2,8	4		5b,c 6a	2a,b,c 4b	
	CU	2			1,2,3,4,5,6	1b 3a,b,d			1,2b 3,5,8	6,7		1a,b 2c	2a,j,k	1c;2d 6	1;2d,e,f,g 3,5,7	6		2,8	4		5b,c 6a	2a,b,c 4b	
	IL	0																					
	IU	0																					
	SM	0																					
C. UPPER YUKON/ PORCUPINE	IL	2	1	3,4,5,6	2	1b 3a,b,d			2b 3,5,8	1,6,7		1a,b 2c	2a,j,k	1c;2d 6	2d,e,f,g 3,5,7	1,6		8		4	5b,c 6a	2a,c 4b	2b
	IU	2		1	2,3,4,5,6	1b 3a,b,d			2b 3,5,8	1,6,7		1a 2c	1b 2a,j,k	1c;2d 6	2d,e,f,g 3,5,7	1,6		8		4	5b,c 6a	2a,c 4b	2b
	SM	0																					
D. TANANA	IL	1	1 2a,c,d	2b 3,4	5,6	1b 3a,b,d			2b 3,5,8	6,7	1	1a 2c	1b 2a,j,k	1c;2d 6	3,5,7	2d,e,f,g 6		8			5b,c 6a	2a,c 4b;5b	2b
	IU	1		1	2,3,4,5,6	1b 3a,b,d			2b 3,5,8	1,6,7		1a 2c	1b 2a,j,k	1c;2d 6	3,5,7	1;2d,e,f,g 6		8			5b,c 6a	2a,c 4b	2b
	SM	1			1,2,3,4,5,6	1b 3a,b,d			1,2b 3,5,8	6,7		1a 2c	1b 2a,j,k	1c;2d 6	1;2d,e,f,g 3,5,7	6		8			5b,c 6a	4b	2a,b
E. YUKON/KOYUKUK	IL	2	1	3,4	2,5,6	1b 3a,b,d			2b 3,5,8	1,6,7		1a 2c	1b 2a,j,k	1c;2d 6	2d,e,f,g 3,5,7	1,6		8			5b,c 6a	2a,c 4b;5b	2b
	IU	0																					
	SM	0																					
F. YUKON/ KUSKOKWIM DELTA	CL	0																					
	CU	0																					
	SM	0																					
G. UPPER KUSKOKWIM	IL	0																					
	IU	2		1	2,3,4,5,6	1b 3a,b,d			1,2b 3,5,8	6,7		1a 2c	1b 2a,j,k	1c;2d 6	1;2d,e,f,g 3,5,7	6		8		4	5b,c 6a	4b	2a,b,c
	SM	0																					
H. COOK INLET	CL	1	1 2a,c	2b,d	3,4,5,6	1b 3a,b,d			2b 3,5,8	1,6,7		1a 2c	1b 2a,j,k	1c;2d 6	3,5,7	1;2d,e,f,g 6		8		4	5b,c 6a	2a,c 4b	2b
	CU	1		1	2,3,4,5,6	1b 3a,b,d			2b 3,5,8	1,6,7		1a 2c	1b 2a,j,k	1c;2d 6	3,5,7	1;2d,e,f,g 6		8	4		5b,c 6a	2a,c 4b	2b
	IL	0																					
	IU	2		1	2,3,4,5,6	1b 3a,b,d			2b 3,5,8	1,6,7		1a 2c	1b 2a,j,k	1c;2d 6	3,5,7	1;2d,e,f,g 6				4	5b,c 6a	4b	2a,b,c
	SM	2			1,2,3,4,5,6	1b 3a,b,d			2b 3,5,8	6,7	1	1a 2c	1b 2a,j,k	1c;2d 6	2d,e,f,g 3,5,7	6	1	8	4		5b,c 6a	4b	2a,b,c
I. COPPER RIVER	IL	0																					
	IU	0																					
	SM	0																					
J. ALEUTIAN	CL	0																					
	CU	0																					
	SM	0																					
K. BRISTOL BAY	CL	1		1	2,3,4,5,6	1b 3a,b,d			1,2b 5,8	3,6,7		1a 2c	1b 2a,j,k	1c;2d 6	1;2d,e,f,g 3b;5,7	3a 6		8			5b,c 6a		2a,b,c 4b
	CU	1			1,2,3,4,5,6	1b 3a,b,d			1,2b 5,8	3,6,7		1a 2c	1b 2a,j,k	1c;2d 6	1;2d,e,f,g 3b;5,7	3a 6		8	4		6a 5b,c		2a,b,c 4b
	SM	1			1,2,3,4,5,6	1b 3a,b,d			2b 5,8	1,3,6,7		1a 2c	1b 2a,j,k	1c;2d 6	2d,e,f,g 3b;5,7	1 3a;6		8	4		5b,c 6a		2a,b,c 4b
L. KODIAK/SELIKOF	CU	0																					
	SM	0																					
M. GULF OF ALASKA	CL/ CU	0																					
	SM	2		1	2,3,4,5,6	1b 3a,b,d			2b 5,8	1,3,6,7		1a 2c	1b 2a,j,k	1c;2d 6	2d,e,f,g 3b;5,7	1 3a;6		8	4		5b,c 6a	4b	2a,b,c
N. SOUTHEAST	CL	0																					
	CU	1		1,2	3,4,5,6	1b 3a,b,d			1,2b 5,8	6,7	3	1a 2c	1b 2a,j,k	1c;2d 6	1;2d,e,f,g 3b;5,7	6	3a	8	4		5b,c 6a		2a,b,c 4b
	SM	2			1,2,3,4,5,6	1b 3a,b,d			2b 5,8	1,3,6,7		1a 2c	1b 2a,j,k	1c;2d 6	2d,e,f,g 3b;5,7	1 3a;6		8	4		5b,c 6a		2a,b,c 4b

K. EXPLORATION AND RECOVERY OF HARD ROCK MINERALS

1. Introduction

Mining techniques are defined depending on whether the activity occurs on the surface or underground, but exploration, recovery, and separation procedures are common to each area of activity. Recovery of the minerals by surface methods is preferred if the overburden is not too thick. Surface operations generally offer safer working conditions, are able to more completely recover the mineral, and have the lowest dollar cost per unit of mineral produced. The primary drawback to this type of operation is that large areas of the surface are disturbed and reclamation must occur before the site is returned to its original state, which may offset the cost savings of operation. In the United States, approximately 80 percent of the ore and fuel is recovered utilizing surface techniques, and 66 percent of the total disturbed land is a result of coal, sand, and gravel recovery. The separation of a mineral from the ore-bearing rocks does not generally occur as part of the mining operation. However, a partial separation and concentration process, called ore dressing, may be carried out at the site to concentrate the mineral so it is more economical to transport for further processing.

2. Resources Required to Complete Action

In addition to labor and equipment, site access and water are the primary requirements for any mining activity. Access development operations are described in earlier discussions on excavation (Section IV.B) and construction filling on land (Section IV.C). The mine operation requires the resources identified in drilling for water (Section IV.G) and road and dam construction (Sections IV.I and IV.J).

3. Permits and Regulations

State and federal agencies regulate the exploration and development of mining operations. The Environmental Protection Agency has regulations for effluent discharge from tailings ponds, sanitary waste facilities, and cooling water. The Alaska Department of Environmental Conservation regulates wastewater disposal, solid waste disposal, and air emissions. Permits are also needed from the Bureau of Land Management for rights-of-way for roads and road alignments. Further interested agencies outside of the permit system are the Alaska Department of Fish and Game and the Bureau of Mines. Lease agreements may stipulate further restraints for construction and operation.

4. Description of Action and Equipment

Initial exploration may utilize gravimetric, geochemical, or geophysical techniques to determine the presence of mineral deposits. A gravity meter may be used to detect dense

rocks buried within lighter rocks and thus indicate mineral-bearing formations. Geochemical prospecting involves systematically collecting hundreds or thousands of samples of rocks, soil, stream sediments, and other elements. These samples are then analyzed to detect differences in mineral concentrations which may indicate the location of hard mineral strata. Direct physical exploration, including trenching or stripping, may be required to remove the overburden and examine the mineral deposit. Mineral recovery requires surface or underground operations in which three common processes occur: rock breaking, mucking (loading), and transporting (hauling and hoisting). The methods by which these three processes are carried out depend upon the type of recovery involved.

Surface recovery normally occurs with an open pit excavation or alluvial techniques. Open pit mining may consist of a quarry or gravel pit, or may entail area or contour stripping of the overburden. Before mining activity begins, the site is cleared, access roads are provided, and a disposal site is prepared for the overburden and waste rock. The requirements for these site preparation actions have been described as basic engineering actions. Area strip mining is practiced on relatively flat terrain. A trench is cut through the overburden, and the spoil is dumped on unmined land adjacent to the cut. After the ore is removed, a second cut is made parallel to the first, and the overburden from this excavation is deposited in the first cut. Shovels with capacities up to 160 cubic yards and 220-cubic-yard draglines are often used to remove the overburden, but spoil and ore characteristics and topography all determine the type of equipment used.

Contour stripping is practiced on rolling hills or steep terrain and consists of removing the overburden from the mineral seam, starting at the outcrop and proceeding around the hillside. This type of mining creates a shelf or bench along the side of the hill which is bordered on the inside by the high wall (unmined material) and on the outer side by the high ridge of spoil material. This type of excavation has greater pollution potential than area stripping because the high walls and spoil piles are subject to severe erosion.

Alluvial mining occurs when water is used during the recovery process and is used most frequently at placer sites where minerals have been transported and deposited near the earth's surface by wind, water, or soil activity. This technique can be as simple as "panning" for gold or conducting crushed ore through a sluice box to separate minerals by specific gravity. Dredging operations utilize a suction apparatus or mechanical device to recover materials from river bottoms. Floating dredges have been used extensively in placer gold mining, but are also popular for removing sand and gravel from streambeds or low-lying areas. Spoil piles from gold dredging operations are similar in configuration to those described above for area and contour strip mining.

Hydraulic mining utilizes powerful jets of water to erode a bank of earth or gravel. The ore-bearing material is then fed through sluices or other concentrating devices where the minerals separate by differences in specific gravity. Hydraulic mining was used

extensively in the past for gold and other precious metal production, but is only practiced on a limited scale today. Both dredging and hydraulic mining create severe sedimentation problems in streams, and their use is strictly regulated by the State.

For surface mining, in addition to the basic steps of site preparation, overburden removal, ore recovery, and transport, the reclamation of the disturbed land must be considered. Experience has shown that reclamation can be conducted more effectively and economically when it is integrated into the planning and operational stages of the mining activity. Much of the machinery used in the mining operation can be used to reduce spoil piles, segregate toxic materials, and control drainage from the site.

Underground mining occurs when surface methods are impractical or uneconomical. Underground mines have been classified by the method of ore removal but, since techniques vary with each situation, any classification scheme is controversial. The basic system involves the excavation of tunnels or shafts (many names are employed, depending upon function and direction) and stopes (areas from which the ore materials are being removed). Site preparation is not as extensive as for surface excavation because smaller areas are required for support facilities. Access roads must also be supplied, but spoil disposal may occur underground in abandoned shafts. Where shafts are not available, surface dumping of spoil material would be required.

The rock-breaking phase of ore recovery occurs either through stoping methods or caving methods. Stopping consists of breaking the rock overhead in a stope by blasting or drilling by hand or with specialized machinery. Machine stoping is limited to soft rock minerals where ripping machines and augers can break the rock without blasting. Caving methods are preferred for very large ore bodies since they do not require reinforced stopes. Caving methods utilize blasting and drilling techniques to essentially undermine a large mass of rock, causing it to cave in and break upon itself.

After stoping or caving methods have been used to break the rock, it must be loaded and transported to the surface. If ore dressing or further processing is required to concentrate the desired mineral, the rock is first crushed and ground. Then it is sorted and sized, and the separation process is accomplished either by hand or by utilizing physical properties of the mineral, such as magnetism, specific gravity, flotation, and hardness.

5. Impacts

a. Air Quality

Air quality impacts associated with exploration for minerals and mining are mainly due to particulates. The access road construction, base camp and airport facilities, and transportation-related emissions are similar to impacts discussed in other engineering

actions of this level and include particulates as well as gaseous emissions. Exploration itself involves some drilling and blasting and may give rise to relatively small pollution loads from clearing and mechanical equipment.

Surface mining techniques, including open pit and placer mining, involve either quarrying or dredging activities. Large amounts of material are moved to get at the valuable minerals, and waste piles or dredge spoils are left vulnerable to the action of the atmosphere, at least temporarily. Wind erosion of these piles is an important factor. The only effective mitigating measure involves a rapid reclamation project progressing at the same time as the mining to restore as quickly as possible a stabilizing layer of vegetative cover. Movement of material into and out of storage piles, vehicular traffic, and wind erosion contribute an estimated 27, 40, and 33 percent of the pollutants, respectively. The quantity of suspended dust emissions in pounds per ton may be estimated by the following expression:

$$\text{Emissions Factor} = \frac{0.33}{(\text{PE}/100)^2}$$

where

PE = Thornthwaite's precipitation/evaporation index
(U.S. Environmental Protection Agency, 1975)

Underground mining operations also generate dust. In most cases, the volumes of material moved in comparison to the amount of ore taken are less. Dust and noxious gases from blasting are serious health hazards in mines. Modern mines include ventilation systems to replace the air with relatively cleaner air. Conditions within an underground mine are governed by OSHA and industry regulations. These regulate the exposure levels to various pollutants.

Once the ore is removed from the ground it is often "dressed" before being transported to the processors, smelters, or refiners that go about removing the waste material and concentrating the purity of the mineral. The impacts of these industries are significant, but are most often removed from the mining site. These industry-related impacts are discussed in Section IV.P, Natural Resource Development Complex.

b. Noise

The overall noise impact associated with mining depends on whether surface or underground techniques are employed. As stated in the introduction, surface techniques account for about 80 percent of the hard rock recovery activities and would invariably

create the greatest community noise impacts. In addition to site preparation and excavation, sorting and crushing of the rock material is often used in gravel pit operations prior to transporting of the material. Site noise levels from mining will vary with the level of activity and size of operation. The noisiest types of equipment employed are generally the rock drill (98 dBA as measured at 50 feet) and the truck (91 dBA as measured at 50 feet). In one study, noise levels from drills operating in two mines were measured at the listener's (operator's) ear and levels of 114 to 124 dB recorded (Spiechowics, 1971). Such high levels are not only hazardous to the worker's ear, but also the nervous system. The overall excavation activities will create noise levels ranging from about 75 to 95 dBA at a distance of 50 feet over the operating life of the project.

Crushing, sorting, and drying of materials are frequently employed at rock quarries, gravel pits, and mines. Noise level measurements from such equipment are shown in Table IV-XIX. These measurements are based on limited data samples; however, the levels indicate that such equipment emits noise levels far in excess of those considered to be harmful to human health.

TABLE IV-XIX. NOISE LEVELS OF SOME MINING EQUIPMENT

Type of Equipment	Noise Level at 50 Feet	Source of Measurement
Rock crusher (diesel)	94 to 95 dBA	John Graham Company, 1976
Rock crusher (electric)	86 to 88 dBA	Washington State Department of Ecology, 1974
Sorter	94 to 95 dBA	John Graham Company, 1976
Dryer	100 dBA	John Graham Company, 1976

Transporting of the mined material is generally accomplished by trucks, rail, or ship. Traffic noise impacts are defined by statistical distribution of noise over time, and an estimate of the worst-case 1-hour volumes would be required to model the roadway noise levels expected and the associated impact expected from truck transport due to mining activity.

c. Water Resources

Exploration may result in impacts similar to those discussed for oil and gas exploration. The primary effects of mineral recovery operations on surface waters are caused by erosion of unstable soil surfaces, overburden disposal areas, and gravel areas, and by leachates from rock wastes and tailings from ore dressing. The potential for water quality degradation is greater for surface mining techniques than with underground operations.

Erosion increases surface water turbidity and stream sedimentation. The effects are discussed in Section II.C.1. Leachates have the potential for depressing stream water pH and increasing concentrations of mineral elements (Section II.C.2). Sulfur-bearing minerals such as coal, when exposed to air and water, may oxidize to form sulfuric acid. Soluble acid salts formed on exposed spoil surfaces may dissolve into water during periods of stormwater runoff. Salts of metals such as zinc, lead, arsenic, copper, and aluminum may also be placed into solution and surface waters from stormwater runoff. Leachates can cause long-term (years) toxic effects. The effects on water quality of site preparation were discussed in the Level I basic engineering actions such as clearing and grubbing and excavation (Sections IV.A and IV.B) and Level II actions such as road construction (Section IV.I).

d. Terrestrial Biology

Exploration and recovery of hard rock minerals initially will have similar effects as those described for clearing and grubbing (Section IV.A), excavation (Section IV.B), road construction (Section IV.I), and community development (Section IV.N). Impacts specifically unique to mining are the extensive surface area disturbed during open pit surface mining (including both the mineral-rich mine and the disposal site on which the overburden and waste rock are dumped), the additional destruction of landscape which can occur from erosion on and surrounding the site because of unstable soil surfaces, and the contamination of surrounding terrestrial environments by toxic leachates from wastes and mineral tailings. Although underground mines are generally not as damaging to surface vegetation because of smaller land areas required for the removal and recovery of minerals, extensive site preparation, waste disposal, and toxic leachates still may pose serious problems to terrestrial vegetation and to important wildlife water supplies.

Critical factors that must be considered before mining ensues are (1) the degree to which the removal of vegetation will influence the region as a whole (Section II.D.2); (2) the extent to which vegetation on the site provides food and shelter to wildlife species; (3) the importance of the site to migrating wildlife; (4) the short- and long-range impacts that sulfuric acid and other toxic leachates will have on vegetation, wildlife, and soil; and (5) potential detrimental effects of significant quantities of heavy metals on plants and wildlife if ingested.

e. Aquatic Biology

The impacts of mineral exploration are similar to those discussed for oil and gas exploration (Section IV.H), since the prospecting techniques for both resources are similar. The impacts of mineral recovery on aquatic life result from changes in water quality, as discussed under water resources in this section. Erosion from excavation and spoil accumulations may result in increased stream sediment loads and the impacts described in Section II.E.1. Contaminated sediment is particularly important near mining operations, since mine wastes often contain significant amounts of heavy metals or other harmful substances which are easily carried to streams in storm runoff. These toxic substances may result in the effects described in Section II.E.2. Coal mining wastes are noted for the production of sulfuric acid, formed when pyrite in the ore is chemically changed in the presence of air and water. The addition of this acid to natural water systems may result in the impacts discussed in Section II.E.4.

Loss of vegetation from land clearing or erosion could increase stream temperatures and affect aquatic life, as described in Section II.E.5. The establishment of camp facilities results in impacts similar to those discussed in Section IV.N, Community Development. Increased human activity generally results in the addition of nutrients to water systems (Section II.E.6). Fuel spills or waste disposal may contribute toxic substances to aquatic systems, with the results indicated in Section II.E.2.

f. Soils

Those impacts described under clearing and grubbing, excavation, and road construction (Sections IV.A, IV.B, and IV.I) are applicable to mining. Additional impacts are as follows.

(1) Erosion and Sedimentation — Although erosion and sedimentation are discussed under clearing and grubbing (Section IV.A), mining has particularly severe erosion and sedimentation potential, due to the degree of disturbance of the land surface and the difficulty in revegetating spoil materials (Curtis, 1969; Hill, 1972). Mine spoils are often acidic, droughty, and excessively stoney, which makes them difficult to revegetate. In turn, the bare earth materials remain highly erodible. Research in Kentucky has estimated sediment yield from mined areas to be as much as 1000 times greater than that of undisturbed areas. During a 4-year period, the average sediment yield from undisturbed forested areas was 25 tons per square mile, while the yield from mining spoil banks was 27,000 tons per square mile (U.S. Department of the Interior, 1967).

(2) Mass Wasting — Mass wasting precipitated by mining has been documented in several instances (Morton and Streitz, 1971; U.S. Department of the Interior, 1967). In Elm, Switzerland, slate quarrying is cited as the cause for a massive

landslide that had a volume of approximately 10 million cubic yards. An even greater landslide at Frank, Alberta, of 34 to 40 million cubic yards is thought to have been caused in part by coal mining. Surface and subsurface mining can initiate mass wasting in a number of ways such as altering drainage, loading of slopes with spoil materials, reducing slope stability by undercutting, reducing subground structural strength, and melting permafrost.

Mass wasting potential for a given site must be developed with regard to site-specific geology, slope, soils, precipitation, permafrost, mining operation, and seismic stability. Conditions which can make an area susceptible to mass wasting include seismic instability, steep slopes, heavy precipitation, permafrost, low strength minerals (e.g., kaolinite), and conditions of perfect cleavage and parallel diagonal orientation of planar elements, as well as young, shallow, unconsolidated porous soils underlain by sloped impervious material.

(3) Subsidence — Subsidence due to subsurface coal mining has been well documented (Scot, et al, 1971; Vandale, 1971). Underground mining can alter the structural stability of the overburden and result in extensive subsidence or subsidence in structurally weak areas. Sink holes and the general instability of these areas often preclude their use for most man-made structures, due to insufficient support for foundations and structural elements.

(4) Changes in Biological, Chemical, and Physical Properties of the Soil — The earth material that remains following surface mining has little resemblance to soil. There are no soil horizons, the material has no soil structure, the flora and fauna of the soil have been largely eliminated, and the pH is usually drastically altered. Crowl and Sawyer (1971) state that

On a mined area, the land is an unorganized mass of parent material (rock, slate and shale) combined with whatever soil that covered it in the undisturbed state. Given enough years to weather, these parent materials may form a completely new type of soil.

On an estimated 20 percent of all spoil sites, vegetation is extremely difficult to establish due to excessive stoniness and/or toxic conditions (U.S. Department of the Interior, 1967); consequently, soil formation can be very slow on some spoil materials.

g. Interactions

Those impacts identified in Excavation and Road Construction (Sections IV.B and IV.I) are also applicable to mining activities. Additional impacts are listed below.

(1) Random samples of spoil material throughout the United States indicate that in 20 of the sites sampled revegetation was hampered due to rapid runoff,

stoney soil conditions, or toxic conditions (U.S. Department of the Interior, 1967). Due to the extreme climatic conditions in many parts of Alaska, revegetation in this state is perhaps even more of a problem. Slow primary succession will probably be required on sites used for excavation of rocky material.

(2) Quarry and open pit mining, dredge mining, and hydraulic mining impose a serious potential for erosion. In a random survey (U.S. Geologic Survey, 1967) estimated that 10 percent of the sites sampled had gullies in excess of 1-foot depth. Sediment deposits were found in 56 percent of the ponds and 52 percent of the streams on or adjacent to the sample site. Secondary impacts of such sedimentation include reduction in spawning habitat for anadromous fish, alteration in makeup of benthic communities, decreased light penetration, and increased nutrient concentrations. Suspended sediments in aquatic environments during downstream migration of juvenile anadromous fish can cause some mortality.

(3) Sampling of nationwide spoil bank materials indicated 1 percent had a pH of less than 3 and 47 percent had a pH range of 3 to 5. Most plants cannot tolerate soil pH of 4 or less. Consequently, reestablishment of vegetation in these spoils may be retarded. In 20 percent of the sites examined, revegetation was extremely difficult due to excessive stoniness or low inhibiting pH conditions (U.S. Geologic Survey, 1967). Free acid is typically leached in 3 to 5 years, allowing revegetation. However, erosion which exposes additional sulfuric minerals will reestablish acidic conditions.

(4) Sulfur-bearing minerals are frequently associated with coal. When these minerals are exposed to air, they oxidize to form sulfuric acid. The acid is transferred to aquatic systems in two ways. Soluble acid salts enter into solution during periods of surface runoff, and groundwater may be altered chemically while moving through spoil (U.S. Geologic Survey, 1967). The extent of potential pollution is exemplified by data gathered in the Appalachians where, in 1965, 194 of 318 sampling stations were measurably influenced by acid mine drainage. In addition, the Bureau of Sport Fisheries and Wildlife estimates 5800 miles of stream and 29,000 surface acres of impoundments have been seriously affected by surface coal mining operations within the continental United States.

(5) Milling wastes from mines producing zinc, lead, and cadmium can release salts of heavy metals that can be lethal to plants, animals, and humans (Pettyjohn, 1972). Heavy metals are selectively absorbed by plants from polluted soils. For example, rice growing in soils containing an average of 6 parts per million (ppm) of cadmium had concentrations of 1250 ppm in roots and 125 ppm in rice (J. Kobayashi, 1969). Herbivores, including man, can rapidly concentrate these lethal heavy metals. Acidic conditions frequently associated with mine spoils further complicate toxic conditions by making heavy metal salts more soluble and facilitating their movement and transfer to adjacent environments (Hill, 1972). Although heavy metals are moved by water, they concentrate in

riverbed sediments and in living food chains (Pettyjohn, 1972). Drainage from non-heavy-metal mines also have heavy metals (e.g., aluminum, sodium, and manganese). Concentrations of these metals in mine drainage vary considerably from mine to mine and region to region (Hill, 1972).

IMPACT ANALYSIS, EXPLORATION AND RECOVERY OF HARD ROCK MINERALS

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	2		3,6	1,2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5	6	2,3,5,7		8	4,2,5,6,7,8	3	2,2,3,4,5,6
	CU	2		3,6	1,2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5	6	2,3,4,7	5	8	4,2,3,5,6	3	2,2,3,4,5,6
	SM	1			1,2,3,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5		4	2,3,7	8		3	4,2,3,5,6
B. NORTHWEST	CL	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6	2,3,5,7		8	4,2,3,5,6	3	2,2,3,4,5,6
	CU	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6	2,3,4,7	5	8		3	2,2,3,4,5,6
	IL	2	1	3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6	7,5	2,3	8		3	2,2,3,4,5,6
	IU	2		1,3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6	2,3,4,7	5	8	4,2,3,5,6	3	2,2,3,4,5,6
	SM	1			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6	4	2,3,5,7	8		3	2,2,3,4,5,6
C. UPPER YUKON/ PORCUPINE	IL	1	1	3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	8	5	2,3,7	8	6,7	3	2,2,3,4,5,6	
	IU	2		1,3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	6	2,3,4,7	5	8	4,2,3,5,6	3	2,2,3,4,5,6	
	SM	2			1,2,3,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	6	4	2,3,5,7	8		3	2,2,3,4,5,6	
D. TANANA	IL	2	1	2,4,5,6,7	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	5	1,5,7			2,3,5,7,8	3	6,7	2,2,3,4,5,6	
	IU	2		1,3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5	6,7		2,3,4,7	5,8	3	4,2,3,5,6		
	SM	2			1,2,3,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	5,7	6		2,3,4	5,7,8	3	4,2,3,5,6		
E. YUKON/KOYUKUK	IL	1	1	3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	6		5,7	2,3,8	3	5,6,7	2,2,3,4,5,6	
	IU	2		1,3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	6	4	2,3,7	5,8	3	4,2,3,5,6		
	SM	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	6	4	2,3	5,7,8	3	4,2,3,5,6		
F. YUKON/ KUSKOWIM DELTA	CL	1		1	2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6	5,7	2,3	8	5,6	3	2,2,3,4,5,6	
	CU	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	5,7	6	2,3,4,7	5	8	4,2,3,5,6	3	2,2,3,4,5,6	
	SM	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,3,4,5,7	6	4	2,3	8	3	4,2,3,5,6		
G. UPPER KUSKOWIM	IL	2	1	3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6		5	2,3,7,8	3	6,7	2,2,3,4,5,6	
	IU	2		1	2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	6		2,3,4,7	5,8	3	4,2,3,5,6		
	SM	1			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	5,7	6		2,3,4	7,8	3	4,2,3,5,6		
H. COOK INLET	CL	1	1	2,2,3,4,5,6	2,2,3,4,5,6	4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5	6,7			2,3,8	3	2,2,3,4,5,6	
	CU	2		1,3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5	6,7	4	2,3	8	3	4,2,3,5,6		
	IL	0																					
	IU	1		1,3,6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5	6,7		2,3,4	8	3	4,2,3,5,6		
	SM	2			1,2,3,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	5,7	1,5	4	2,3	8	3	4,2,3,5,6		
I. COPPER RIVER	IL	2	1,3	6	2,4,5	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	5,7	1,5,7	5	2,3,7	8	3	4,2,3,5,6		
	IU	0																					
	SM	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1,2,3,4,5,6	5,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	5,7	1,5,7	4	2,3	7,8	3	4,2,3,5,6		
J. ALEUTIAN	CL	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,2,3,4,5,6	6				2,3,8	3	5,6	2,2,3,4,5,6
	CU	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	7	1,2,3,4,5,6	8	4	2,3	8	3	4,2,3,5,6	
	SM	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	6	4	2,3	8	3	4,2,3,5,6		
K. BRISTOL BAY	CL	2		1	2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	6				2,3,8	3	5,6	2,2,3,4,5,6
	CU	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	6		4	2,3	8	3	4,2,3,5,6	
	SM	1			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	1,5,7	6	4	2,3	8	3	4,2,3,5,6		
L. KODIAK/SHELIKOF	CU	2		1	2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	4,7	1,5	4	2,3	8	3	4,2,3,5,6		
	SM	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	4,7	1,5		1,5,6,7	2,2,3,4,5,6	4	2,3	8	3
M. GULF OF ALASKA	CU	2		1,2,3,6	4,5	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	4	5,7	3,6	4	2,3	8	3	4,2,3,5,6	
	SM	2		1,3,6	2,4,5	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	4,7	1,5	6	4	2,3	8	3	4,2,3,5,6	
N. SOUTHEAST	CL	0																					
	CU	2		1,2,3,6	4,5	1,2,3,4,5,6		3,6,7	1	5,7	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	5,7	3,6	4	2,3	8	3	4,2,3,5,6	
	SM	2			1,2,3,4,5,6	1,2,3,4,5,6		3,6,7	1	2,3,4,5,6,7	8	1,2,3,4,5,6	1,2,3,4,5,6	2,2,3,4,5,6	4	1,7	6	4	2,3	8	3	4,2,3,5,6	

L. COMMERCIAL LOGGING

1. Introduction

Southeast Alaska contains the most productive forestland in the state. The forest in this region is typical of the temperate rain forest lying along the west coast from northern California to Cook Inlet. Most of the growth is old and undisturbed by man. Species are western hemlock (74 percent), Sitka spruce (12 percent), western red cedar (5 percent), Alaska cedar (5 percent), and mountain hemlock and other softwoods (4 percent). The two most common commercial species are western hemlock and Sitka spruce.

Logging also occurs in other regions of Alaska, but not to the same extent as in the southeast. Much of the timber cut in these sections is for local construction and use. Interior taiga or boreal forests of spruce hardwoods extend north from the Kenai Peninsula to the Brooks Range, stretching in a broad band across the continent. Typically, the spruce hardwood forest consists of white spruce, black spruce, birch, aspen, and balsam poplar. These forests cover 32 percent of the land or about 106 million acres, but only one fifth (21 million acres) are classified as commercial forestlands. In spite of the greater acreage, there is less yield in these regions than in the southeast due to harsher climatic conditions.

Commercial logging operations utilize several silvicultural practices, foremost among which are clear-cutting, selective cutting, and seed tree and shelterwood cutting. In many cases, cutting practices selected are influenced by (a) silvicultural characteristics of the trees, such as light, water, nutrients, and growing space requirements; (b) physical and biological characteristics of the environment that affect regeneration and growth; (c) management objectives; (d) economic objectives; (e) environmental incompatibilities including cutting where erosion is detrimental to existing conditions (e.g., streamside alluvial terraces, shorelines, steep slopes); and (f) human use incompatibilities (e.g., areas of improved forest stands exhibiting camping and other recreational values, aesthetic values). There are disadvantages to each cutting method and these may be especially severe if logging practices are unregulated and proper mitigating procedures are not maintained.

2. Resources Required to Complete Action

Timber must be available in commercial quality and quantity. Species and size are determining factors. In an unprocessed state, timber is unmarketable, except for firewood or Christmas trees, and a sawmill or pulpmill is required to process the resource into useful materials. Living facilities, a water supply, and a waste disposal system are required for logging operations in remote areas. Energy demands vary according to the size of the operation, but fuel must be provided for equipment, and a generator usually produces power for camp facilities. Space heating can be by wood, coal, electricity, or natural gas.

Equipment can be barged, flown, trucked, or hauled by rail to the timber sale area. Personnel are usually flown. Roads must be maintained and constructed to allow accessibility of equipment to forested areas for cutting. A means of transport is also required for removal of logs from the cutting site to the mill (typically by boat, raft, haul truck, or rail).

Construction materials can be divided into two categories: native or indigenous and fabricated. Logs, gravel, and fill are classified as native or indigenous materials. Fabricated materials include prefabricated buildings, trailers, guardrails for bridges, concrete and asphalt, plumbing and electrical fixtures, furniture, and foundation materials.

Typical logging equipment includes chain saws, logging shears, bulldozers, trucks, choker chains and grapples, blocks and cables, skidders, tractors, cable systems, heelboom loaders, front end loaders, tugs, and A-frame swings. Hardware includes corner blocks, bullblocks, rigger blocks, skyline knock-out pin shackles, guyline sleeves, and cable clamps. Other necessary equipment might include climbing spurs, belts, and ropes, splicing ropes and hammers, rigger mauls and bar axes, saw wedges and hoists, and pass chairs.

3. Permits and Regulations

State regulations are given in Alaska Statute Title 38, Public Lands; Chapter 95, Alaska Land Act; Article 4, Disposal of Timber and Materials; and are administered by the Division of Lands. The Alaska Department of Environmental Conservation may attach stipulations concerning water quality, and the Department of Fish and Game may attach stipulations concerning fish and wildlife habitats.

The U.S. Corps of Engineers requires permit application and approval for construction in navigable waterways (Section 10) and dredging and filling (Section 404). The U.S. Forest Service administers permits and regulations regarding specific conditions (Section AT), standard provisions (Section BT), and special provisions (Section CT) for timber sale contracts.

4. Description of Action and Equipment

Operations described here characterize silvicultural techniques and associated logging practices which are conventionally used in southeast Alaska to perpetuate the forests on a sustained-yield basis. The operations described are based upon the biological requirements of each tree species and are designed to maximize wood production. Silvicultural techniques range from clear-cutting to selective cutting, each affecting forest regeneration differently. Because clear-cutting is the most commonly practiced logging technique, this action and commonly used equipment will be emphasized.

Clear-cutting is designed to achieve maximum regeneration and growth of new stands of selected tree species. Clear-cutting results in extensive regeneration and implies the establishment at one time of numerous evenly distributed seedlings, resulting in even-aged mature stands. This method essentially removes all merchantable trees in a given area. In Alaska, clear-cuts are limited to 160 acres on federal lands. The location and actual size of the clear-cut unit is further determined by terrain, seed dispersal, erosion, and the disposal of litter into nearby streams. Clear-cutting appears to be the silvicultural system that most nearly meets biological and economic objectives according to commercial interests. For spruce regeneration, this practice offers more light and available nutrients, which this species requires. However, in southeast Alaska shade and windbreaks are necessary and in even-aged stands, where serious brush competition develops, this practice should be avoided and replaced by the shelterwood system.

The seed tree method is another cutting practice. A unit is clear-cut with the exception of a small number of seed-bearing trees left either singly or in groups to provide seed for regeneration. The seed tree method also achieves concentrated regeneration over the cut area. However, it may be an impractical method for southeast Alaska because of wind damage to remaining trees and because seed dispersal is usually adequate from adjacent noncut areas.

The shelterwood method removes the overstory in stages, and the remaining trees provide seed and shelter for regeneration. The overstory is removed in two or more successive cuttings. The shelterwood method prepares the way for the establishment of seedlings, with a final cut to release them once they are established. Again, the cutting results in concentrated regeneration and an even-aged mature stand. The shelterwood method is not used commercially in Alaska, although it has been used experimentally to protect hemlock and spruce seedlings from brush competition (Ruth, 1967; Williamson, 1966).

The selection method is the periodic cutting of selected trees from a large area. Mature trees are cut to allow for growth of smaller trees and because of their higher commercial value. This method is not used extensively in Alaska, although it is used somewhat in the interior regions where growth is slow and a number of trees are of little commercial value. This method results in diffuse regeneration and uneven-aged stands.

Clear-cutting has been the most common logging practice in Alaska. Much of the forest in the southeast is in climax or near-climax successional condition. Clear-cutting has a rejuvenating effect on these old-aged stands, allowing the establishment of new seedlings. These new seedlings display increased growth, vigor, and yield. With clear-cutting in the cut area, less road construction for access is required. Windthrow damage is decreased by exposing less timber edge per unit area of cutover land. Clear-cutting effectively removes decayed and diseased growth. A major drawback of clear-cutting is aesthetic, particularly in

scenic or recreational areas. Other drawbacks of clear-cutting include a reduction in protection from erosion, landslides, and rapid water runoff; undesirable species claiming the site; loss of exposed trees in adjacent stands; loss of wildlife habitat; and loss of scenic and recreational areas. Large clear-cuts greater than 200 acres have had detrimental effects on environmental qualities, as have massive landslides initiated by clear-cutting and poor road construction methods.

During a normal logging operation in an uncut tract, initial timber removed is used in camp and road construction. Logs are felled, landed along the road, or yarded. Roads are constructed and surfaced with gravel. Landing and decking areas (temporary placement sites for logs before they are loaded onto trucks) are prepared through excavation and filling.

The actual logging operation, shown in Figures 4-4 and 4-5, utilizes a high-lead cable system for both uphill and downhill yarding. Because the terrain is steep (35 to 70 percent slopes), long-line and short-line cable systems constitute 90 percent of the systems in Alaska. On flatter terrain, rubber-tired skidders and tractors are used for yarding. The churning of treads or tires and ground dragging have been shown to be especially damaging to the soil layer. There is a decreasing trend in tractor logging because of its proven damage to the site (Harris and Farr, 1974).

The cable system consists of a mobile tower, a four-drum yarder mounted on a truck chassis, a tailspur, a slack-pulling skidder carriage, cables, and wires. This skidder system uses a five-man crew and handles 200 to 250 logs per day. The unit can yard logs effectively to distances of up to 1500 feet. Often considerable embankment and excavation is required for safe and well-stabilized placement of the cable system. Guy wires and stabilizing lines must be attached to secure points around the tower to hold the system in place.

Timber is usually cut by a single faller using a gasoline-powered chain saw. A skilled faller can cut 50,000 board feet per day. The stump height must not exceed the diameter of the tree, but timber is often cut much lower to the ground, which conserves wood and reduces the number of unsightly stumps. The trees are limbed and cut, and the slash, or waste wood, is evenly distributed over the cut area. Usually two or three cut logs are attached to the slack-pulling skidder carriage and yarded to landing areas. The cable system lifts the logs entirely off the ground during transport. Environmentally, this is much more advantageous than tractor yarding. Tractors tend to churn up the soil with their tires. This method also involves more dragging of logs and a more extensive road system. Balloon yarding (where large air-filled balloons carry logs downhill) has also been used, resulting in less soil disturbance and requiring less extensive road systems.

TIGHTENING THE SLACKPULLING LINE RAISES AND ROTATES THE TONGLINE SHEAVES, MAKING CONTACT WITH THE IDLER SHEAVES, RESULTING IN A VISE LIKE GRIP ON THE TONGLINE. APPLYING A LOAD TO THE TONG LINE RELEASES THE GRIP

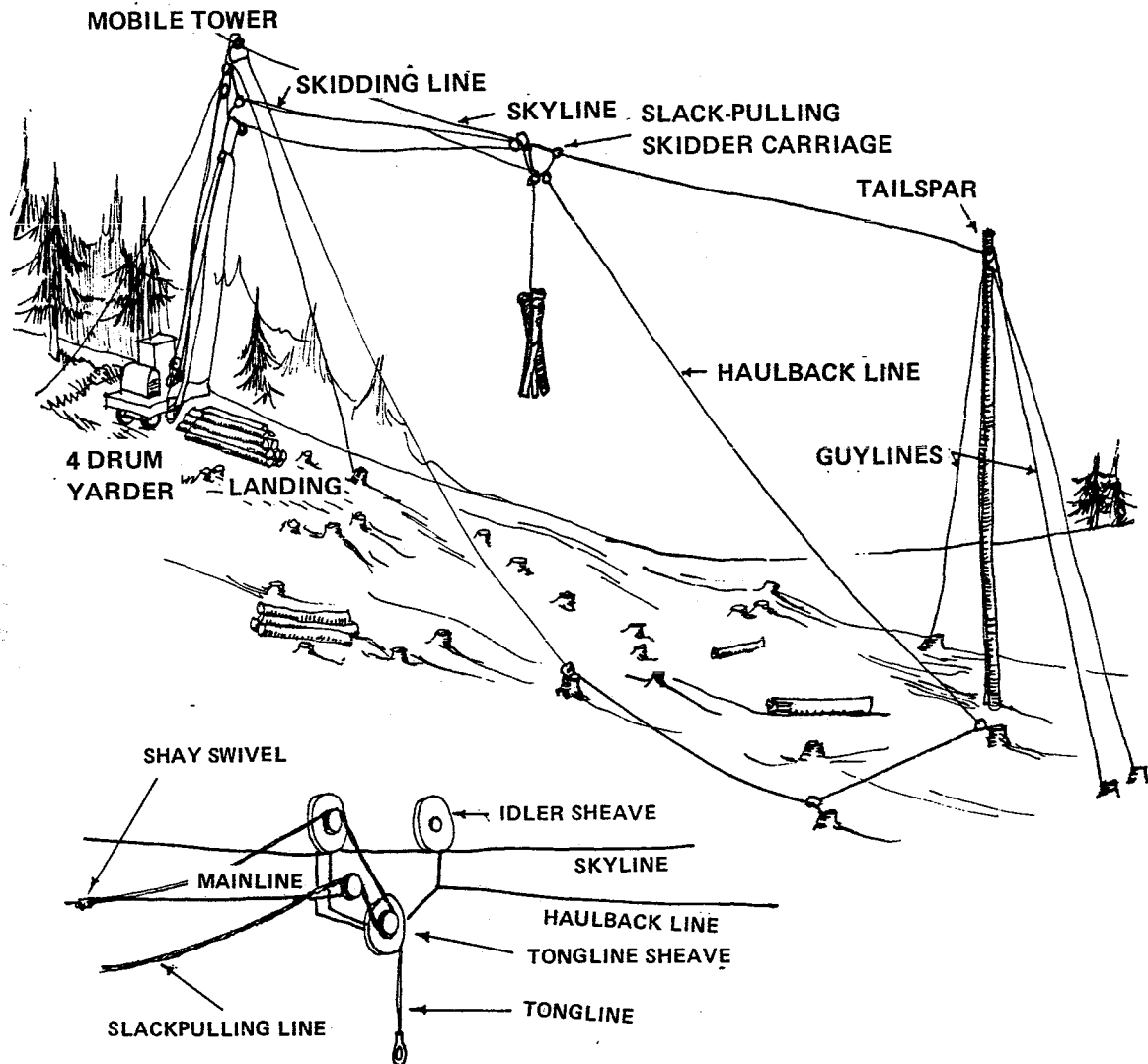
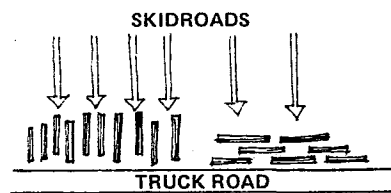
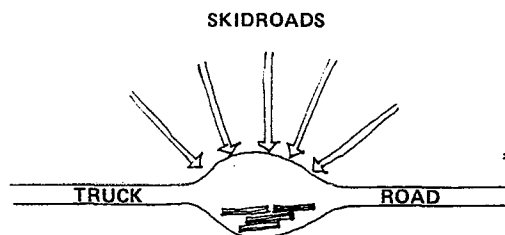


Figure 4-4. Skidder System for Commercial Logging



CONTINUOUS LANDING



CENTRALIZED LANDING

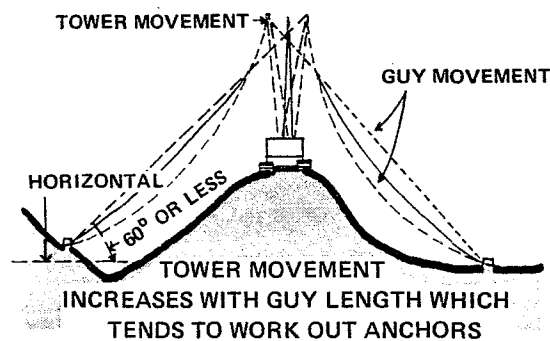
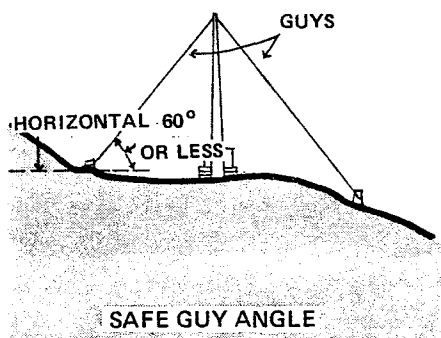
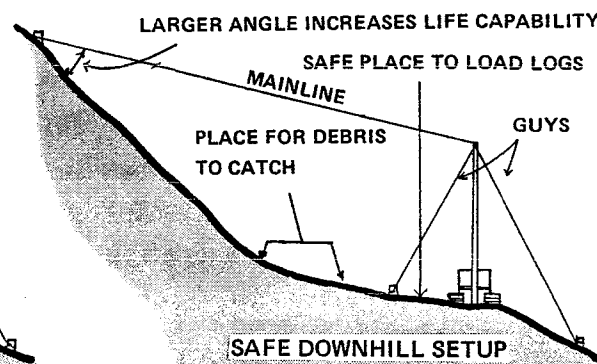
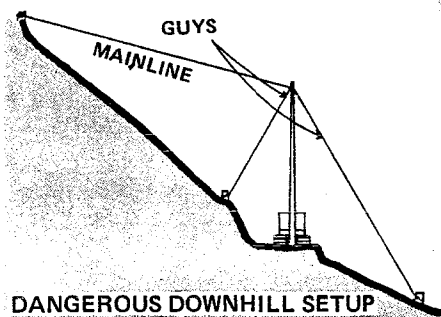
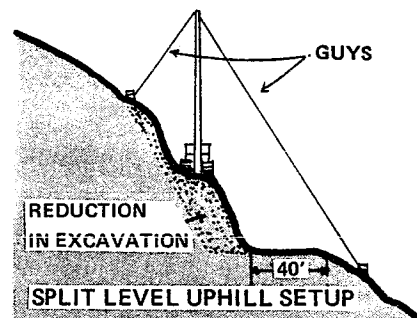
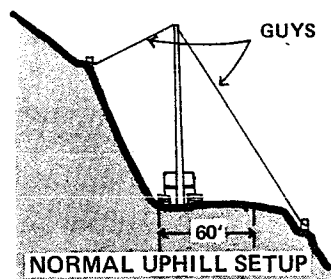


Figure 4-5. Landing Location for Commercial Logging

After the logs are landed, they are moved to decking areas to await further transport to the mill. Logs may be transported by water in large raft-like formations which release bark and fiber into the water. At completion of the logging activities, cleanup work is started to restore the site and minimize the effects of the camp development. Streambanks are restored to minimize the flow of sediment into the waterways, and the existing roads are graded and regravelled to meet minimum secondary road standards. The clear-cut units will be left to reforest naturally.

5. Impacts

a. Air Quality

Commercial logging results in air quality impacts from construction of access roads, transportation, establishment of base camps, the use of heavy equipment which burns diesel fuel or gasoline, refuse burning to clear the land, and those processes that convert the wood to usable products. The particulate and gaseous emissions resulting from road construction and establishment of base camps are described in the section on road construction (Section IV.I). The use of heavy-duty equipment will result in gaseous emissions, as shown previously in Table IV-V.

The open burning often practiced as the final process in clear-cutting before replanting (if any) is a most significant source of pollutants. Table IV-I shows some of the emission rates for various pollutants from open burning. The burning of forests and forest wastes appears to be a major contributor to airborne particles. Estimates of national totals of airborne particles are shown in Table IV-XX. The actual cutting of the trees and dragging to the trucks stirs up fugitive dust as well, but contributes much less to the potential impact.

The processing of the wood represents a major source of emissions, although this does not take place on the logging site. Wood pulping, pulp board manufacture, and plywood veneer and layout operations are included in these processes. The particulates, sulfur dioxide, and odors emitted are significant, but are considered under the section on natural resource development complex (Section IV.P).

b. Noise

In most commercial logging operations the most common noise sources are skidders and chain saws. In a study by Myles, et al (1971), noise level readings from these operations were taken at the operator's ear at 15 and 50 feet. Table IV-XXI shows the results of these measurements. In this study, the maximum distances at which noise from logging operations were audible were determined. In the average situation, chain saw noise could be heard to a distance of 1.43 miles and skidder noise to a distance of 1.45 miles. Depending on terrain, wind speed and direction, density of vegetation, and other environmental factors, these distances could vary markedly.

TABLE IV-XX. SELECTED SOURCES OF
AIRBORNE PARTICLES BASED ON INPUTS
(million metric tons per year)

Sources	U.S. Total Particles of All Sizes *
Agriculture and forestry burning	
Forest	6.09
Crop wastes and ranges	2.18
Forest cleaning	(no reliable data)
Grain processing	0.73
Mining	1.45
Waste incineration	1.0

* NAPCA, 1970

TABLE IV-XXI. AVERAGE NOISE LEVELS OF LOGGING
EQUIPMENT AT VARIOUS MEASUREMENT DISTANCES

Distance	Type of Equipment	
	Skidders	Chain Saws
At operator's ear	104 dBA	106 dBA
At 15 feet	89 dBA	94 dBA
At 50 feet	83 dBA	86 dBA

Source: Myles, et al, 1971

In a second study on propagation of sound waves from logging equipment in forests (Myles, et al, 1971b), it was found that, in addition to divergence decrease due to distance, sound propagation through extensive forests has a reasonable attenuation of 2 dB per 100 feet. This value fluctuates due to wind and other factors, so it is not constantly accurate. The authors conclude that, in order to prevent intrusiveness of noise to campers, logging operations should not be permitted closer than 1 mile from camping locations. In areas where such use conflicts might be expected, reductions at the noise source would also help reduce the distance that the noise would travel. For example, a 6-dB reduction can be obtained by muffling, which would reduce by 40 percent the distance at which the noise could be heard.

Other noise sources associated with logging, including camp construction and transport of workers and equipment, are discussed in previous sections of this report. Noise levels associated with other types of logging equipment (bulldozers, trucks, tractors, and loaders) are discussed in Section II.B.

c. Water Resources

Soil disturbance by forest roads crossing steep slopes and unstable soils can increase the potential of soil erosion and stream sedimentation from precipitation and stormwater runoff. Similar disturbances may occur in harvest areas; however, the magnitude may be lessened because forest litter dissipates the impact of rainfall intensity. The effects of increased turbidity in surface waters are described in Section II.C.1.

When streamside vegetation is removed, water temperatures may increase several degrees. The magnitude of the increase, however, depends on such factors as volume of stream flow, groundwater influences, length of channel exposed to solar radiation, and general climatic conditions. Although drastic changes are observed in small streams, small lakes and estuaries are most seriously affected. An increase in temperature could contribute to a decrease in dissolved oxygen concentrations, described in Section II.C.3.

The storage and transportation of logs may also cause water quality degradation. Bark and other debris knocked off logs at dumping sites and in raft storage areas may settle to the bottom and create a dissolved oxygen demand during biodegradation (Section II.C.3). Leachates also are released when logs are stored or transported in water. Leachate concentrations can be toxic, cause changes in pH from tannins, and create an oxygen demand. These effects are described in Sections II.C.2, II.C.3, and II.C.4.

d. Terrestrial Biology

Commercial logging in Alaska will exhibit many of the impacts previously described in Section II.D. Specific references to these impacts are outlined below.

- Drastic changes in the plant community (Section II.D.1.a)
- Dislocation of mobile birds and mammals and death to small localized populations of amphibians, reptiles, and mammals (Sections II.D.1.b and II.D.2.j)
- Reduction of primary energy and productivity of a site (Section II.D.2.a)
- Changes in the soil/water balance and other soil characteristics (Section II.D.2.b,d,e)
- Sudden and frequently severe impacts on perimeter species (Section II.D.2.f)
- Landscape fractionalization (Section II.D.2.k)
- Increased fire, insect, and fungal outbreaks (Section II.D.2.g,h,i)
- Local air, solid waste, and noise pollution (Sections II.D.3.a, II.D.5, and II.D.7)

In every logging operation, prompt and adequate restocking of cutover land is the prime concern; and it is the speed with which these objectives are met that will determine the severity of impact to the terrestrial environment. Forest managers can control the size, pattern and timing, amount of fire control, slash disposal, amount of scarification, fertilization, drainage, and seeding, and it is these factors in each logging operation that will determine specific short- and long-range impacts on future regeneration and colonization by plants and animals. Clear-cuts in general are valuable to wildlife because they are colonized by herbaceous, shrubby, and broadleaf tree species. However, in large clear-cuts these food species may be unavailable because of deep winter snow, so it is small protected clear-cuts that provide most of the winter forage. Generally, the faster the cover grows and the longer it remains open, the more productive it will be for wildlife. For this reason, open stands of widely spaced trees are most beneficial to most animal species.

In Alaska commercial logging will remove older forest stands that are the preferred or exclusive habitat for some animal species (e.g. marten, flying squirrels, woodpeckers, spotted owls, bald eagles). Under current management practices, young developing stands will eventually be cut before they develop into old growth forests, so habitat for many of these species will be permanently reduced.

The general influence of herbicides and fertilizers on terrestrial ecosystems is described in Section II.D.4, and specifically described in this section under Interactions (Section IV.L.5.g).

e. Aquatic Biology

Impacts associated with logging normally occur as a result of increased stream sedimentation which affects aquatic life, as discussed in Section II.E.1. The construction of logging roads removes vegetation and increases susceptibility to erosion. Tree removal also stimulates erosion by removing the vegetation which stabilizes the upper layers of soil. Shallow streams may be forded by trucks, resulting in further streambed and bank erosion and in gravel compaction, which may prevent salmonid spawning. Vegetation removal increases surface runoff which carries nutrients to waters flowing from the area. These nutrients, normally available to terrestrial vegetation, enter the aquatic system where they may increase plant growth, as described in Section II.E.6.

Nutrients are also introduced when fertilizer is used to stimulate revegetation of logged areas. These nutrients may be introduced to the aquatic system through direct application or in stormwater runoff. The removal of vegetation near streambanks also may increase the sunlight reaching the stream, and thus may increase the water temperature. The effects of this change are discussed in Section II.E.5.

Temporary storage of logs in water may result in decreases in pH and dissolved oxygen. Tannins and other organic acids are slowly leached from logs and can contribute to localized acidity in a poorly circulating body of water. This pH change may affect aquatic life, as discussed in Section II.E.4. Bark and other debris from log storage areas which accumulate on the lake or stream bottom are degraded anaerobically and may lower dissolved oxygen levels in some areas (Section II.E.3). Considerable deposits of organic debris may build up and when suspended may cause a rapid decrease in the amount of oxygen available for aquatic life.

f. Soils

Those impacts described in the sections on clearing and grubbing (Section IV.A) and road construction (Section IV.I) are generally applicable to commercial logging. However, commercial logging repeatedly removes nutrients due to repeated removal of timber and losses through leaching and erosion at each cutting cycle. If these losses are greater than the nutrient inputs to the site between cuttings (e.g., subsoil mineralization, fertilization, nitrogen fixation, and precipitative inputs), the nutrient capital of the soil can be depleted and the soil may become unproductive. Soils vary greatly in their nutrient content and in their ability to withstand leaching. Forest timber also varies greatly in its nutrient makeup (Simmons, 1974). Consequently, predicting soil depletion requires site-specific

information. Fertilization, immediate revegetation, and leaving the nutrient-rich tree crowns on site are mitigating measures which can reduce nutrient losses to the soil, but conversely may increase fire hazards.

g. Interactions

Clearing and grubbing and road building are engineering actions required for commercial logging operations. Consequently, impacts associated with these actions are applicable to commercial logging. Additional impacts specific to this resource extraction activity are identified as follows:

(1) Pesticides — A number of pesticides are frequently used in forest management: insecticides to control insect infestation, herbicides to control "weed" trees or other competitive vegetation, fungicides to control infestation, and animal repellents to reduce browsing on desired tree species. Other potentially toxic substances are used for seed coating to reduce seed predation, and some toxins are used to remove or reduce undesirable species (e.g., deer mice) from a site. In Alaska there has been only a limited application of such pesticides to date. However, hand application of insecticides in the vicinity of campgrounds has been reported. Also, moderate use of the herbicide 2,4-D has occurred along roadways and by aerial application to a few areas.

The long-term consequences of herbicides are simply not known (Evans, 1974). The use of these chemicals has not resulted in any immediate or significant deleterious effect to nontarget species or communities (Meehan, 1974). Application of DDT (0.28 kg/hectare) on Prince of Wales Island between 1961 and 1964 to control black-headed budworm did occur. In a subsequent study of the area, Reed (1966) reported that no direct short-term mortality occurred to fish species, although aquatic insect populations were drastically reduced which would, presumably, have significant effects on rearing species of salmonids (e.g., coho, Chinook, sockeye, rainbow, and Dolly Varden). In addition, organic chlorines have been strongly linked to reproductive failures of raptorial birds (e.g., bald eagles and peregrine falcons).

(2) Fertilizers — The use of fertilizers in forest within the conterminous United States is extensive. However, fertilization in Alaska has been limited but will probably increase in the future. Area fertilizers have been traditionally used at a rate of 200 pounds of nitrogen per acre. Ammonia nitrogen is a toxic derivative of the urea fertilizer which, in most conditions, is quickly removed through nitrification. However, nitrification in northern areas of Alaska is limited and urea applications in these areas may result in potential hazardous levels of toxic ammonia nitrogen. In some cases nitrogen will be transferred to aquatic systems, although the amounts transferred are generally thought not to affect aquatic productivity (Meehan, 1974; Norris and Moore, 1971).

(3) Soil Temperature — Clear-cutting results in increases in soil temperature. Consequently, as shown in Table IV-XXII, nutrient release from organic detrital material is increased due to increased microbial action. Increased nutrient transfers to aquatic systems cause increases of algae and slime bacteria in the receiving waters. These increases occur particularly in streams with low gradient and obstructed flows, and in small lakes and ponds (Schmeeje, et al, 1974). This effect may be more pronounced in the interior of Alaska where the soils have large amounts of accrued organic materials.

TABLE IV-XXII. NUTRIENT CONTENT OF SOILS AND
SURFACE WATER BEFORE AND AFTER TIMBER HARVEST¹
(in milligrams per liter)

Nutrient	Surface Water (creeks)		Soil Water			
			Tokeen Soils (well drained)		Wadleigh Soils (somewhat poorly drained)	
	Timbered	Clear-Cut	Timbered	Clear-Cut	Timbered	Clear-Cut
Nitrate	0.062	0.094*	0.055	0.116*	0.067	0.195*
Phosphate	0.86	1.04	1.02	0.914	0.76	0.915
Iron	0.07	0.15*	0.1	0.07	0.1	1.30*
Calcium	1.72	1.45	1.30	2.23*	1.38	2.35*
Magnesium	0.185	0.24	0.16	0.34*	0.20	0.17
Potassium	0.52	0.85*	0.35	0.70*	1.68	2.65*
Sodium	1.12	1.16	1.60	2.26*	1.15	1.15
Organic carbon	4.8	6.3	7.0	12.5	7.0	30.0*

* Indicates that differences between samples from clear-cut and timbered areas are probably real, judging by the magnitude of difference and variation between duplicate samples. Analysis by the Federal Water Quality Laboratory, Fairbanks, Alaska.

¹ U.S. Department of Agriculture, Forest Service Environmental Statement, Ketchikan Pulp Company Timber Sale 1974-1979 Operating Period. On file, U.S. Forest Service, Juneau, Alaska.

IMPACT ANALYSIS, COMMERCIAL LOGGING

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	0																					
	CU	0																					
	SM	0																					
B. NORTHWEST	CL	1			1,2,3,4,5,6	1b 3a,d		1c	1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1 3a	6,7	2c,d,e,f,g 4,5	5,7	2,3,8		2a,c;4a 5a;6b	3	
	CU	0																					
	IL	0																					
	IU	0																					
	SM	0																					
C. UPPER YUKON/ PORCUPINE	IL	1	1	3	2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1 3a	6,7	2c,d,e,f,g 4,5		2,3,8	6b	2a,c 4a;5a	3	
	IU	1		1,3	2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1 3a	6,7	2c,d,e,f,g 4,5	2,3,4		4a	2a,c 5a	3	
	SM	0																					
D. TANANA	IL	2	1,3 2a,c,d	2b	4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1 3a	6	2c,d,e,f,g 4,5,7		2,3,8		2a,c 5a;6b	3 4a	
	IU	2		1,3	4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1 3a	6	2c,d,e,f,g 4,5,7	2,3,4	8		2a,c 4a;5a	3	
	SM	0																					
E. YUKON/KOYUKUK	IL	1	1	3	2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1 3a	6	2c,d,e,f,g 4,5,7		2,3	8	2a,c;4a 5a;6b	3	
	IU	1		1,3	2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1 3a	6	2c,d,e,f,g 4,5,7	2,3,4	8		2a,c 4a;5a	3	
	SM	0																					
F. YUKON/ KUSKOKWIM DELTA	CL	1		1	2,3,4,5,6	1b 3a,d		1c	1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	2,3	8	6b	2a,c 4a;5a	3	
	CU	0																					
	SM	0																					
G. UPPER KUSKOKWIM	IL	1	1	3	2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7		2,3,8		2a,c 5a;6b	3 4a	
	IU	1		1,3	2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 8	2c,d,e,f,g 4,5,7	2,3,4	8		2a,c 4a;5a	3	
	SM	0																					
H. COOK INLET	CL	2	1 2a,c;3	2b,d	4,5,6	1b 3a,d		1c	1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7		2,3,8		2a,c 4a;5a	3 4a;5a	
	CU	2		1,3	2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	2,3,4	8		2a,c 4a	3 5a	
	IL	0																					
	IU	0																					
	SM	0																					
I. COPPER RIVER	IL	1	1,3		2,4,5,6	1b 3a,d	1c		1,3,5,6		2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	2,3	8		2a,c 4a;6b	3 5a	
	IU	0																					
	SM	0																					
J. ALEUTIAN	CL	0																					
	CU	0																					
	SM	0																					
K. BRISTOL BAY	CL	1		1	2,3,4,5,6	1b 3a,d		1c	1	3,5,6	2b 5,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7		2,3,8		2a,c	3 4a;5a	
	CU	0																					
	SM	0																					
L. KODIAK/SHELIKOF	CU	2		1,3	2,4,5,6	1b 3a,d	1c		1	3,5,6	2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	4	2,3	8		2a,c 4a	3 5a
	SM	0																					
M. GULF OF ALASKA	CU	1		1,2,3	4,5,6	1b 3a,d	1c		1		2b 3,4,5,6,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	4	2,3	8		2a,c 4a;5a	3
	SM	1		1,3	2,4,5,6	1b 3a,d	1c		1	3,5,6	2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	4	2,3	8		2a,c 4a	3 5a
N. SOUTHEAST	CL	2		1	2,3,4,5,6	1b 3a,d		1c	1		2b 3,4,5,6,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7		2,3,8		2a,c	3 4a;5a	
	CU	2		1,2,3	4,5,6	1b 3a,d	1c		1		2b 3,4,5,6,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	4	2,3	8		2a,c 4a;5a	3
	SM	2		3	1,2,4,5,6	1b 3a,d	1c		1	3,5,6	2b 4,7,8	1a;2a,b,c,d 2a;f,g,h,i,j,k	1b 6,7	1c 4	1	3a 6	2c,d,e,f,g 4,5,7	4	2,3	8		2a,c 4a;5a	3

M. AGRICULTURE

1. Introduction

Agriculture concerns the production and harvest of plants and animals for food and other products. Alaska, although the largest state in the Union, exhibits the smallest acreage devoted to agriculture. Three areas in Alaska produce nearly all of Alaska's agricultural crops. These are Matanuska Valley, Tanana Valley, and the Kenai Peninsula (listed in order of relative importance). The major crops presently grown are small grains, forages, potatoes, vegetables, fruits, and ornamentals. Each crop involves a different method of agriculture. Amounts of fertilizer, acreage, irrigation, and pesticides and herbicides vary with each crop. Following is a brief description of each of these crops. The activities discussion involves an in-depth study of methods involved in a potato and vegetable farm in the Matanuska Valley.

Small grains grown in Alaska are all of the spring-sown type. The later summer-sown (winter) type of small grains are either insufficiently winter-hardy or too late in maturity for dependable use in Alaska. Barley is important for cattle feed and the hardiest and most widely grown of the grain crops. The dominant variety is Edda, introduced from Sweden. Oats are another major grain crop grown in Alaska. Oats mature later than barley and are less frequently grown. Oats are used for grain to some extent, but their major use is for forage. Grain production involves the largest acreage per farm. An average grain farm is 1000 to 2000 acres in size.

The potato is a particularly hardy food plant and well suited to production from sea level to 1000 feet above sea level along the coast and in the major river valleys south of the Brooks Range. The two most common varieties are the Alaskan russet and the Alaskan frostless, both adaptable to long periods of sunlight and cool climates. Two thirds of the potatoes are grown on small farms (50 to 100 acres) in the Matanuska Valley, one third of the harvest is from the Tanana Valley, and a few are grown in the Kenai Peninsula.

Cool season vegetables such as radishes, turnips, cabbages, cauliflower, broccoli, brussel sprouts, peas, carrots, onions, leaf lettuce, head lettuce, and rhubarb grow well in Alaska. Most vegetables grown are for home use or are sold at roadside stands and local retail outlets. Development of a vegetable processing plant in Alaska could encourage the production of these vegetables.

In Alaska, 16 native plant species produce fruits of economic importance. These include blueberry, bearberry, cloudberry, high-bush cranberry, crowberry, red currant, black currant, elderberry, gooseberry, lingonberry, nagoonberry, raspberry, strawberry, serviceberry, and mountain ash. Hybridization of native fruits with similar lower latitude species could possibly produce winter-hardy commercial crops. Successful experiments have

been carried out with strawberries, but they have not been produced commercially. Research in the Cook Inlet has shown that Descue, an apple/crabapple variety, is winter-hardy and produces attractive edible apples.

Ornamentals are plants used for landscape and interior design. The local bedding plant and nursery industry is expanding and providing adapted hardy species for these purposes.

2. Resources Required to Complete Action

The most agriculturally productive soil in Alaska is silt loam, a loess overlying a gravelly or sandy base. This premium soil is situated on gentle slopes of generally less than 12 percent grade. When the soil is approximately 15 to 20 inches deep, it usually remains moist enough to require little irrigation during a year of normal precipitation. However, precipitation in some areas is very limited and irrigation may be required to maintain productivity. Water for irrigation is available in quantities far beyond present demands in all of the agricultural portions of the state. However, cold water temperatures may require that settling ponds and spraying be employed prior to using such water. A scant percentage of the surface runoff is utilized, and groundwater potential is many times that of current development.

Applications of fertilizer increase the yield of most Alaskan soils, because much of the available nutrients remain in the organic matter which is removed by clearing. Additions of potassium have reduced leaf necrosis on potatoes grown in the Matanuska Valley, and the addition of phosphorous and lime to soil in the Kenai Peninsula area has dramatically improved the yield of barley. Generally, many Alaskan soils are deficient in nitrogen, potassium, and sometimes phosphorous; therefore, commercial fertilizers combining these three elements are the most useful. Strongly acidic soils must be limed heavily to produce favorable plant growth.

Most of the seed used in Alaska is obtained from Alaskan crops, since many of the varieties of vegetation grown are adapted to northern latitude agriculture and are not used elsewhere. Usually the first year's crop produces enough seed for the next season's planting. Maximum yields are generally obtained in four or five years after the initial planting with seed put aside each year for the following season.

Farm production in Alaska is as mechanized as anywhere in the United States. Due to the short planting season, seed must be put into the ground as quickly as possible to ensure maximum yields. Experiments have shown that missed planting days in the spring result in noticeably lower yields, and harvesting must be accomplished with equal rapidity to ensure minimum damage by early frost. Late frost can also affect crop success in some areas of the state.

Fuel for the operation of farm machinery is another resource requirement. Quantities needed depend upon the location and size of the operation and the agricultural crops grown.

3. Permits and Regulations

Pesticide use permits are the only permits required for agriculture in Alaska. Rules and regulations for the use of pesticides may be found in the *Federal Register*, Volume 39, Number 85, "Pesticides and Pesticide Containers." In addition, pesticide use must be approved by the Alaska Department of Environmental Conservation.

4. Description of Action and Equipment

The first phase of activities in a farming operation requires the removal of the natural vegetation, which entails extensive clearing and excavation. The trees are stacked in berm piles on the edge of the cleared land and burned. Oftentimes, two or three burnings are required to totally reduce the wood to ash, due to the high moisture content of the green wood. This has been known to cause a forest fire hazard. After the initial clearing, extensive plowing is required to incorporate the remaining organic material into the soil. Roots, limbs, and forest humus must be broken down by repeated plowing to achieve a relatively uniform soil consistency.

In recent years, a new method of clearing has been initiated in which a bulldozer pulls a rotary plow which shreds the organic growth. This method entails less plowing and reintroduces more of the organic material back into the soil. Much of the initial clearing is done in the winter, and in the following summer the field is plowed and allowed to lie fallow. It is not until the following spring that crops are introduced.

Irrigation is required to increase yield and improve crop quality during dry periods. Irrigation also extends the growing season by forcing earlier seed germination and protecting crops from early frost damage. Two areas in Alaska which would benefit most from supplemental irrigation are the Yukon region, particularly around Fairbanks, and the Tanana River Basin and Matanuska River Valley in the south central region. Research on crop water requirements indicates that oats and potatoes require 13.7 and 11.8 inches per growing season, respectively, with peak requirements during maturation, which occurs in mid to late summer. The peak water requirements for hay and pasture have been established as 0.12 inch per day in the Matanuska Valley. This amount is a total of 15 inches for the entire 100-day growth season, and irrigation is required to ensure maximum crop production in years when precipitation is below this level.

There are four basic types of irrigation: gravity flow (including furrow and border irrigation), sprinkler, subirrigation, and drip. Sprinkler irrigation is by far the best method of

water control, and most systems in Alaska are a combination of the solid-set and hand-move lateral systems. If the setup is left in place for the season, cost per acre increases for investment, but the labor costs are kept low. The water can be obtained from either groundwater or surface runoff.

Insect pests are not a severe problem in Alaska because most insects are controlled by natural predators and cold temperatures. Crop rotation and destruction of crop residue by burning after harvesting are also effective means of controlling pests. Cutworms have cyclic population increases and can cause extensive damage to cabbage crops. Restrictions on the use of chlorinated hydrocarbons have made control of these pests more difficult, but nonpersistent chemicals such as diazinin and trichlorfon (dylex) usually are successful. Diazinin must be worked into the soil, which is difficult during the growing season. Trichlorfon is easier to apply, but requires more frequent application. Other pests which can be controlled by the use of diazinin and malathion include the turnip maggot, aphids, and red beetle. Herbicides, primarily 2,4-D, are commonly used in Alaska for weed control. They are normally applied before planting to kill forb and weed species which establish themselves in disturbed habitats.

Most soils in Alaska require fertilization, since most nutrients are contained in the organic growth which is removed during clearing. Ashes from the burned vegetation may be spread over the cleared area to alleviate this problem. The rotary plow method of clearing, which shreds organic growth and reintroduces it into the soil, is another way to recycle these nutrients. However, these two methods cannot overcome the natural deficiency of some soils with respect to certain nutrients.

Well-balanced commercial fertilizers contain nitrogen, phosphorous, and potassium. Strongly acid soils must be limed to secure a favorable environment for plant growth. Lime (calcium carbonate) reduces soil acidity, supplies calcium, and makes soluble iron and aluminum less toxic. Minor elements, such as boron and molybdenum, are also required in special cases. Liming often results in a boron deficiency which is eliminated by adding 0.5 to 1 pound of boron per acre. Allowing a field to lie fallow for a season also increases the nutrients in the soil.

5. Impacts

a. Air Quality

Emissions to the atmosphere related to agricultural processes come from the clearing of the land, filling, fertilizer production, and product processing after harvest. All of these involve transport, and hence the use of heavy-duty vehicles, with their emissions. The initial clearing of the land involves the basic clearing and grubbing actions and results primarily in emissions of fugitive dust and emissions from burning. The quantity of dust

emissions from agricultural tilling, in pounds per acre of land tilled, may be estimated (within plus 20 percent) using the following empirical expression:

$$\text{Emissions Factor} = \frac{1.4 s}{(PE/50)^2}$$

where

s = Silt content of surface soil (percent)

PE = Thornthwaite's precipitation/evaporation index

This equation, which was derived from field measurements, excludes dust which settles out within 20 to 30 feet (6 to 9 m) of the tillage path. For agricultural tilling, about 80 percent of the emissions predicted by the equation above are likely to remain suspended indefinitely.

In general, control methods are not applied to reduce emissions from agricultural tilling. Irrigation of fields prior to plowing will reduce emissions, but in many cases this practice would make the soil unworkable and adversely affect the plowed soil's characteristics. Control methods for agricultural activities are aimed primarily at reduction of emissions from wind erosion through such practices as continuous cropping, stubble mulching, strip cropping, limited irrigation of fallow fields, windbreaks, and use of chemical stabilizers. Agricultural field burning is a common means of disposing of field stubble and peats. It also represents a major source of emissions to the atmosphere. These emissions are summarized in Table IV-XXIII.

The agricultural industry involves the use of fertilizers, herbicides, and pesticides to increase yields. The manufacture of fertilizers causes pollutants to be emitted to the atmosphere. Nitrogen fertilizer manufacture causes particulates, nitrogen oxides (NO_3), and ammonia to be emitted. Phosphate fertilizer manufacture emits particulates and fluorides as well as those pollutants associated with the mining of phosphate rock. Herbicides and pesticides result in different problems. Depending on the method of application (often airborne seeding), the volatility of the chemicals or the particle size, and the meteorological conditions, these chemicals may be transported to areas beyond those intended for application. Since some crops are sensitive to herbicides, care must be taken as to the occurrence of the crops, even 100 miles downwind of application.

Grain elevators are primarily transfer and storage units and are classified as either the smaller, more numerous country elevators or the larger terminal elevators. At grain elevator locations the following operations can occur: receiving, transfer and storage,

TABLE IV-XXIII. EMISSION FACTORS FOR OPEN BURNING
(in pounds per ton)

Pollutant	Agricultural Field Burning	Landscape Refuse and Pruning	Wood Refuse
Particulates	17	17	17
Sulfur oxides	neg	neg	neg
Carbon monoxide	100	60	50
Hydrocarbons (CH ₄)	20	20	4
Nitrogen oxides	2	2	2

Source: U.S. Environmental Protection Agency, 1973

cleaning, drying, and milling or grinding. Many of the large terminal elevators also process grain at the same location. The grain processing may include wet and dry milling (cereals), flour milling, and distilling. Feed manufacturing involves the receiving, conditioning (drying, sizing, cleaning), blending, and pelleting of the grains, and their subsequent bagging or bulk loading. Typical particulate emissions from these processes are shown in Table IV-XXIV.

The effects of agriculture on climate are generally small. Irrigation may moderate summer temperature and relative humidities to some extent. The change from grass to crops has very little effect on albedo and other surface features. Change from forest to crops increases the albedo (particularly when snow-covered), decreases the water available to the atmosphere (unless irrigated), and decreases the roughness.

b. Noise

The major noise sources associated with development of agricultural crops are from the initial clearing activities and from plowing and harvesting equipment. Clearing generally creates a short-term noise impact on the site which ranges from 83 to 87 dBA at 50 feet. Heavy equipment used for plowing and harvesting is not unlike that currently used in the construction industry. Similarly, the goal with agricultural machinery should be to reduce the noise levels so as to prevent hearing loss to the machine operator (Yoerger, 1971). Noise levels from heavy-duty farming equipment range from 73 to 96 dBA at 50 feet. At the worker's ear (approximately 3 to 6 feet) these levels can reach as high as 114 to 115 dBA with no abatement technology employed. These levels are far in excess of those known to cause hearing loss in a majority of the population and also far greater than those levels set by OSHA for hearing conservation.

c. Water Resources

The removal of natural vegetation to provide cropland for agricultural purposes exposes surfaces which increase the potential for soil erosion and stream sedimentation from precipitation and stormwater runoff to surface waters. The effects of increased turbidity in surface waters are described in Section II.C.1.

However, irrigation return flows are the major factor in influencing the overall water quality of surface waters. These water quality changes consist primarily of an increase in temperature (Section II.C.5) and turbidity (Section II.C.1). Pesticides, herbicides, and fertilizers are also carried into surface waters by overirrigation or the application of pesticides and fertilizers in excess of crop requirements. The effects of the latter are described in Sections II.C.2 and II.C.6. The magnitude of the impacts depends upon the volume of return flow and other drainage entering an irrigation canal, its length, and whether it is lined or unlined.

TABLE IV-XXIV. PARTICULATE EMISSION
FACTORS FOR GRAIN HANDLING AND PROCESSING

Type of Source	Emissions (pounds/ton)
Terminal elevators	
Shipping or receiving	1
Transferring, conveying, etc.	2
Screening and cleaning	5
Drying	6
Country elevators	
Shipping or receiving	5
Transferring, conveying, etc.	3
Screening and cleaning	8
Drying	7
Grain processing	
Corn meal	5
Soybean processing	7
Barley or wheat cleaner	0.2
Milo cleaner	0.4
Barley flour milling	3
Feed manufacturing	
Barley	3

Source: U.S. Environmental Protection Agency, 1973

Leaching and ion exchange are also mechanisms by which concentrations of chemical constituents can be increased several times greater than in the applied water. The method of water application, type of crops, and fertilizers and pesticides applied have no marked effect on return flow water quality unless there is overirrigation or application in excess of crop requirements. Irrigation has the effect of raising the natural groundwater table and altering the groundwater quality.

d. Terrestrial Biology

The agricultural use of land will remove the natural vegetation, thereby influencing the animal communities endemic to the site (Sections II.D.1 and II.D.2). The effects of substantive vegetation removal are described in Section II.D.2. Particularly important are the effects of vegetation removal on primary production and energy flow, soil characteristics, native perimeter species, and landscape characteristics (Section II.D.2). Chemicals, pesticides, and fertilizers influence nontarget plants and animals, as described in detail in Section II.D.4 and in the subsequent sections on soils and interactions.

The characteristics and ecological effects of monocultures within ecosystems have been described in Section II.D.7 and may have great importance in Alaska because of the severe environmental constraints. Specifically, there are fewer agricultural crops that may be grown in Alaska (e.g., only two varieties of potatoes and a few grains), which means less diversity, and therefore less stability and greater loss in the event of unseasonably poor weather or insect and disease outbreak. The short growing season means that crop phenology will be highly synchronized. Therefore, an insect and disease attack will be able to spread rapidly, especially since all crop species will be at identical development stages. In the event of a successful attack, replanting will not be possible because of the short and rapidly changing growing season. If a crop fails, an entire year must be bypassed before a second attempt can be made.

e. Aquatic Biology

Agriculture may result in increased sedimentation of streams due to input from irrigation return waters which contain suspended sediment. Brush and tree removal and overgrazing reduce organic materials which stabilize the ground surface and may result in erosion, which affects aquatic life, as described in Section II.E.1. Pesticides and herbicides are transported to watercourses in runoff and may impact aquatic life, as discussed in Section II.E.2. Fertilizer runoff to water bodies may also result in the effects described in Section II.E.6. Feedlot operations, in which large numbers of animals are concentrated and fed before slaughter, have resulted in water quality problems in the lower 48 states. Since the wastes from the animals are concentrated, stormwater runoff from the confined area carries them to streams where they act as nutrients for the lower forms of aquatic life.

f. Soils

Those impacts described under clearing and grubbing and road building are generally applicable to agriculture. Additional impacts are as follows:

(1) Erosion — Agricultural activities often require annual removal and turning over of vegetation (harvest, tillage) on the farmed land. Consequently, at least once a year bare earth becomes susceptible to erosion by air and water. In addition, farmed areas leave a variable amount of the surface unvegetated (e.g., space between row crops), which is kept weeded and remains susceptible to erosion. Albrecht (1971) states

Continuously cultivated soils, when plowed and mechanically put under granular form by tillage machinery, are quickly hammered by the rainfall into surface slush. This seals the pores and prevents rapid infiltration of water. Water that would be beneficial were it stored in the soil is compelled to run off and represents not only loss of water but also a source for serious erosion of the surface. . . .

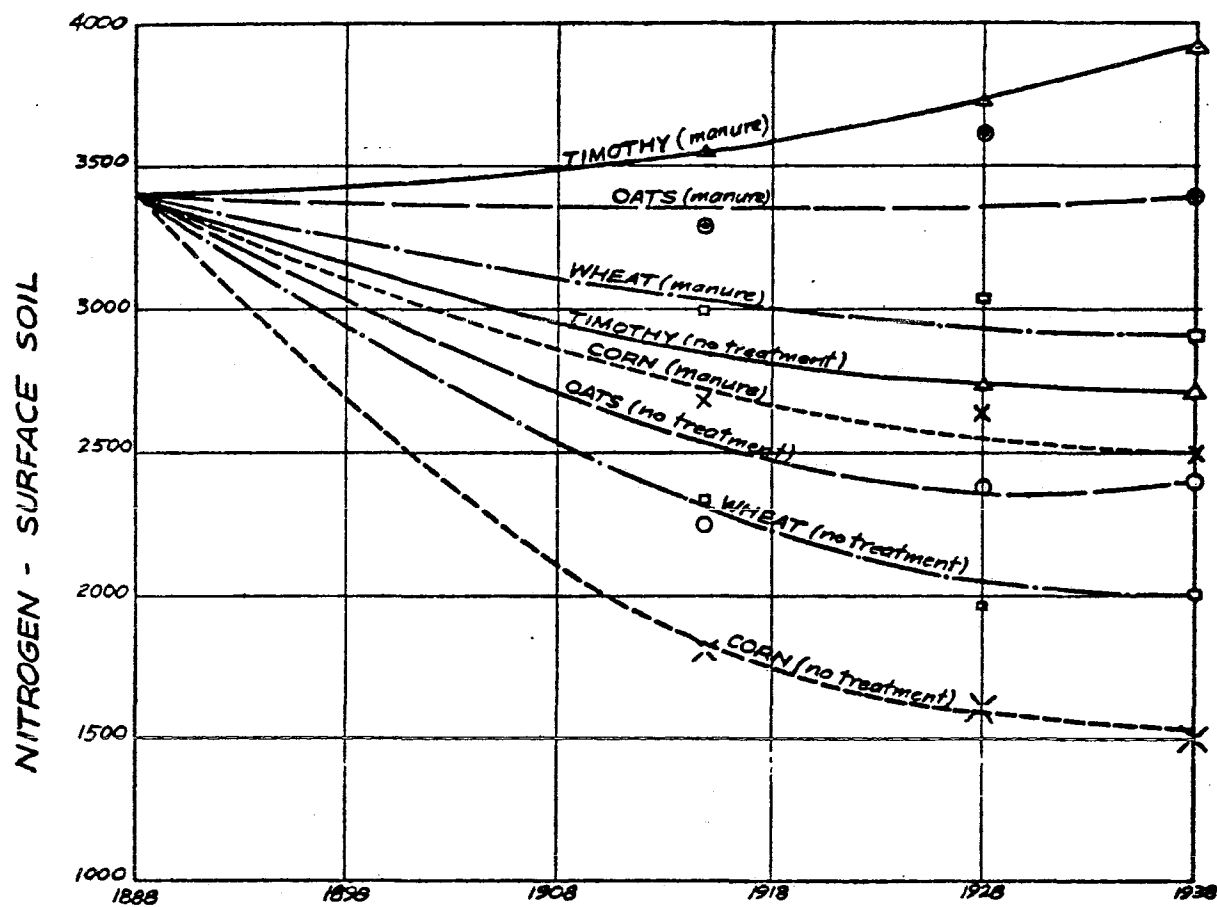
The use of hedge rows, contour plowing, cover crops, and terracing can mitigate erosion losses. However, even with these measures, some erosion is unavoidable.

(2) Changes in Biological, Chemical, and Physical Properties of the Soil — As was described in Section IV.A, Clearing and Grubbing, agricultural practices tend to increase soil temperatures and temperature extremes. However, in the case of agriculture this change in soil condition remains over a long period of time as an effect of the continued agricultural activity. Also, as discussed in Section IV.A, soil pH increases in disturbed taiga soils. Farmers often manage the soil pH by adding lime. Consequently, a higher soil pH can be expected to be maintained in soils used for agriculture.

Plowing and disturbing the soil surface result in increased soil temperatures, which increases microbial activity and decomposition of organic material within the soil. Consequently, nutrients are released at an accelerated rate until the humus of the soil is decomposed. Concurrently, nutrients are removed from the soil by crop removal. Different soils have differing amounts of nutrient capital and have differing rates at which they gain or lose nutrients. If the removal of nutrients through crop removal and other losses exceeds the nutrient input of the soil, the soil becomes exhausted of its nutrients. Depletion of soil nutrients (nitrogen) caused by continuous cropping is illustrated in Figure 4-6. Adding various fertilizers can compensate for some nutrient losses. However, most commercial fertilizers are not complete and, though they may maintain growth and production, the quality of the foodstuffs produced is apt to be reduced.

g. Interactions

The effects of agricultural development on interactions are listed as follows:



Source: Albrecht, 1971

Figure 4-6. Declines in Total Nitrogen of the Soil During Fifty Years of Continuous Cropping with and without Manure

(1) Agricultural development can be expected to increase erosion and subsequent transfer of nutrients and sediment from terrestrial to aquatic systems. Potential secondary effects are reduction in spawning habitat, alteration in makeup of benthic communities, decreased light penetration, increased nutrient concentrations, and loss of soil fertility potential. The extent of erosion is suggested by information presented by Pyrdé (1972). In the USSR, 30 to 35 million acres of tilled lands are affected by water erosion, 20 to 25 million hectares of croplands are affected by wind erosion, and 1.8 percent of agricultural lands are heavily eroded.

(2) Agricultural activities require the use of a number of pesticides for the control of nuisance species. However, secondary undesired impacts have resulted from the use of fungicides, insecticides, and pesticides. Although they are directed at a single or a few pest species, pesticides do affect ecosystems. Appraisal of the effects of pesticides on nontarget populations must remain tentative due to the general lack of information on population dynamics, toxicity, and feeding habits. A number of pesticides are nonspecific in their action, and their effects are density-independent. Different pesticides vary greatly in their toxicity, persistence, and solubility.

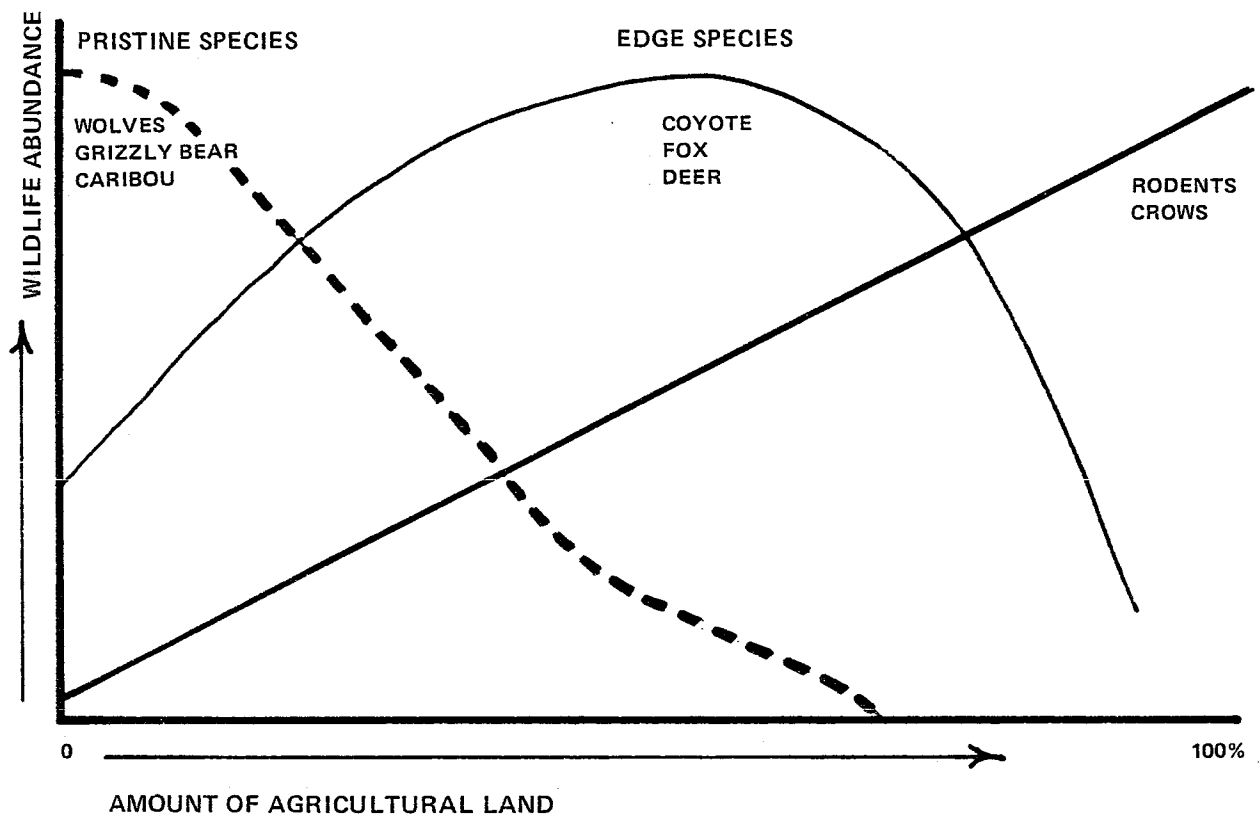
Responses to particular pesticides vary greatly among species, age groups, and individuals. Effects are synergistic and are often dependent on additional environmental factors such as pH, temperature, or the presence of other stresses (Moore, 1971). Significant sublethal effects on reproduction and/or behavior have been documented (Ratcliffe, 1967; Wurster, 1969). Persistent fat-soluble organochlorines have become widely dispersed and concentrated in food chains. Pesticides are apt to be most severely felt by predators, particularly in the case of the fat-soluble organochlorines. Pesticides affect freshwater aquatic systems more than terrestrial systems. Due to natural selection, resistant strains of pests can develop, causing a qualitative change in the species (Moore, 1971).

(3) Potential effects of agricultural development on wildlife populations are demonstrated by the sequence of events which followed such development in Europe and North America. By following this historical sequence, it is possible to predict potential effects of agricultural development in Alaska. The following impacts are given as typical, although in some cases mitigating measures may be possible.

As the land is opened and cleared for crops and pasture, forest species are reduced due to elimination of suitable habitat and increased predation. Large species, which potentially compete with man by preying on domestic animals or crops, are most severely affected (e.g., grizzly bears, wolves, wolverine). Smaller forest species are more slowly reduced in numbers as suitable habitat is altered to farmland. Similarly, as forests are cleared, forest edge species initially increase. Opening forests but still leaving suitable sections of cover establishes optimal conditions for species such as coyote, deer, and fox. However, as lands are further cleared and available cover is reduced, these species also begin

to decline and are typically replaced by species which have very limited cover requirements (rodents), are highly mobile (crows), or are burrowers (gophers). Such species are apt to compete with man for crops and often become "pests." Figure 4-7 illustrates the effects of agricultural development on wildlife.

Wetlands in areas of developing agriculture have historically been reduced by draining, diking, or filling and then used as cropland or pasture, or have been left with little shore cover. Wetland fauna, both resident species (such as muskrat, mink, and beaver) and transient species (such as waterfowl and reed-dwelling species), have been reduced due to the reduced quantity and quality of wetlands. Species able to use large bodies of water and fly long distances to agricultural areas for feeding (e.g., mallards and Canadian geese) seem to do well under altered wetland conditions.



Source: Taber (undated)

Figure 4-7. Effects of Developing Agriculture on Wildlife

IMPACT ANALYSIS, AGRICULTURE

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	0																					
	CU	0																					
	SM	0																					
B. NORTHWEST	CL	0																					
	CU	0																					
	IL	0																					
	IU	0																					
	SM	0																					
C. UPPER YUKON/ PORCUPINE	IL	1	1	3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	5,7	2,3	3 6.b	2.a,b 4.a	5.a,c
	IU	1		1,3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	5,7	2,3		2.a,b 4.a	5.a,c 6.b
	SM	0																					
D. TANANA	IL	2	1 2.a,c,d	2.b 3	4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	5,7	2,3	3	2.a,b 4.a	4.a 5.a,c
	IU	2		1,3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	2,3,7	4	3	2.a,b 4.a	5.a,c
	SM	0																					
E. YUKON/KOYUKUK	IL	1	1	3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	5,7	2,3	3	2.a,b 4.a	4.a 5.a,c
	IU	1		1,3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	2,3,7	4	3	2.a,b 4.a	5.a,c
	SM	0																					
F. YUKON/ KUSKOKWIM DELTA	CL	1		1	2,3,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	2.c,d,e,f,g 3.a;6	1,5		8	5,7	2,3	3 6.b	2.a,b 4.a	5.a,c
	CU	0																					
	SM	0																					
G. UPPER KUSKOKWIM	IL	1	1	3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8		2,3,5,7	3	2.a,b 4.a	4.a 5.a,c
	IU	1		1,3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	2,3	4,7	3	2.a,b 4.a	5.a,c
	SM	0																					
H. COOK INLET	CL	2	1 2.a,c	2.b,d 3	4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a	5,6		8		2,3	3	2.a,b 4.a	4.a 5.a,c
	CU	2		1,3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6 2.b	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a	5,6		8		2,3,4	3	2.a,b 4.a	5.a,c
	IL	0																					
	IU	0																					
	SM	0																					
I. COPPER RIVER	IL	1	1	3	2,4,5,6		1.b 3.a	1.d 3.b,d,f	1,3,4,5,6	8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	5,7	2,3	3	2.a,b 4.a	5.a,c
	IU	0																					
	SM	0																					
J. ALEUTIAN	CL	0																					
	CU	0																					
	SM	0																					
K. BRISTOL BAY	CL	1		1	2,3,4,5,6		1.b 3.a	1.d 3.b,d,f	1	2.b 3,4,5,6,8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8		2,3,5,7	3	2.a,b 4.a	4.a 5.a,c
	CU	1			1,2,3,4,5,6		1.b 3.a	1.d 3.b,d,f	1	2.b 3,4,5,6,8	7	1.a:2.a,b,c,d 2.a,f,g,h,i,j,k	1.b,c 3.a,b;4;7	5,6	1;2.c,d,e,f,g 3.a;6	5		8	2,3	4,5,7	3	2.a,b 4.a	5.a,c
	SM	0																					
L. KODIAK/SHELIKOF	CU	0																					
	SM	0																					
M. GULF OF ALASKA	CU	0																					
	SM	0																					
N. SOUTHEAST	CL	0																					
	CU	0																					
	SM	0																					

N. COMMUNITY DEVELOPMENT

1. Introduction

New communities may develop as Alaska's timber, mineral, coal, oil, and gas resources are exploited. These communities will either provide facilities for the production of resources or will become service centers associated with the network required to transport products in their raw or refined states. Villages subject to periodic destruction from seasonal flooding and beach migration may also seek new town sites at less hazardous locations instead of relying on costly preventive maintenance programs. A three- or four-year construction period could be expected for the development of a new community of 200 housing units; approval by state and federal agencies could add an additional one to two years to development. Construction in each community will provide housing, storage, school and recreation facilities, and community facilities including an airport and water and electric utility systems. The sizes of some typical Alaskan communities are given in Table IV-XXV.

Types of community settlement activity likely to occur in Alaska include movement of small communities due to flood or erosion hazards, or the establishment of new communities to support extraction complexes. Typical activities would include construction of 60 housing units and 70 storage units, plus community facilities to serve small (circa 300) populations covering a few acres. New communities to support resource extraction complexes may require housing and other community facilities (e.g., schools, parks, shopping, banks) for a population of 1000 or more people and may require 75 acres of land or more.

2. Resources Required to Complete Action

In addition to labor and equipment, a suitable site, access, and water supply are primary requirements for the development of a new community. Resources related primarily to site development, access, and water supply are described in earlier discussions on clearing and grubbing, excavation, construction filling, foundation construction, and drilling for water. Other resources required for a community can be viewed as systems.

a. Housing

The first system, and possibly the most important, is housing or shelter. There are four principal types of housing structures: wood frame, modular, trailer, and combination. The term "combination" refers to structures serving a dual function. For example, a school may also serve as housing, or a house may also provide warehousing space. Generally, 500 to 750 square feet is a minimal space requirement for a family of three in rural Alaska (Shishmaref Relocation Effort, August 1974). Most structures consisting of more than 750 square feet are combination or storage buildings.

TABLE IV-XXV. COMMUNITY HOUSING STATISTICS

Place	Population	Housing Units
Anchorage	124,542	16,152
Barrow	2,104	395
Bethel	2,104	717
Fairbanks	45,864	5,231
Juneau	13,556	2,273
Homer	1,083	368
King Salmon	202	70
Kotzebue	1,696	420
Metlakatla	1,050	230
Nome	2,488	833
Palmer	1,140	379
Seward	1,587	591
Unalakleet	450	120

Source: U.S. Department of Commerce, Bureau of Statistics, 1972

b. Public Utilities

Public utilities are another system needed to retain a community's viability. Systems such as water supply and distribution, sewage collection and treatment, and electrical generation and distribution are needed. In some cases, these systems in rural Alaska may not conform to conventional public utility systems.

(1) Water — There are three principal water resources available for rural communities: water from nearby rivers, groundwater, and deep wells. For a community of 200 homes, 100,000 gallons of water per day can be anticipated for domestic use only. This is about 150 gallons per person per day, with an average flow of approximately 300 gallons per minute. Combining fire protection and domestic uses, about 250,000 gallons per day may be required for a community of 200 homes. A closed-loop system could be employed to distribute the water. This system consists of a central pumping station and pipes running to all homes, then returning to the central pumping house. A gray water system may also be employed. This system utilizes two circulating systems from the pumphouse instead of one. One system circulates water for washing, drinking, and domestic use, and the other system is used for sewage.

(2) Sewage — A critical factor in sustaining a community is collection and disposal of raw sewage. Several methods are available to communities. First, there are chemical toilets or "honey buckets," with pickup and dumping provided by the local community. Incineration is a second method employed in sewage disposal, and a third method employs the use of sewage lagoons and consists simply of dumping the sewage into a hole and then filling the hole. Perhaps the best of all disposal systems for a community of 200 homes, given suitable geologic and soil conditions, is primary sewage treatment using individual septic tanks. The advantage of this system over the gray water system is its nondependency on a central pumping house. Further, septic tank sewage is broken down by bacteria, and the by-product can be used for fuel or fertilizer.

(3) Solid Waste — The Alaska Public Health Service requires the collection and disposal of solid waste refuse. Either the local municipality or some other individual or group within the community is responsible for pickup and disposal. Disposal is usually in a landfill.

(4) Stormwater — Storm drains may be needed. Rural communities seldom include street paving in their initial planning stages. However, this does not negate the necessity for the eventual employment of a storm drainage system.

(5) Telephone — Telephone services within the community may be provided. The primary company supplying this service is General Telephone Company, a private utility with headquarters in Seattle.

(6) Power — Electrical generation is an important system within a community, providing convenience and comfort in an inhospitable environment. It should be mentioned that electrical facilities are not required for homes. All Alaskan communities with more than 1500 people have electric utility systems. Many smaller communities also have electric power systems, but there are still communities that do not have electricity. There are approximately 30 utilities serving the rural communities of Alaska. The highest kilowatt-hour (kw-hr) generation is 250, and the lowest is 27 (in Kodiak). Generally, communities with large populations, access to year-round water or land transportation systems, and interconnections with large electric power distribution networks or established hydroelectric generating facilities have the lowest power rates. In terms of a community of 200 homes, the rates might be very high unless the community system was connected with a large distribution network.

c. Transportation

Transportation systems are another component of a community. The prevailing systems are local roads, waterways, and air transportation. Some communities rely heavily on riverboats and snowmobiles for local transportation rather than on automobiles.

(1) Roads — Not all rural communities are required to provide traffic rights-of-way. Local roadways are generally provided for in community development, but may not be designed for heavy automobile usage. Generally, most small Alaskan communities have very few automobiles.

(2) Airstrips — Air transportation may be essential to the well being of the community and its residents. In such cases, an airstrip would be needed to accommodate aircraft. The airstrip's width and length depend upon the size of the aircraft serving the community. For a community located near the water, aircraft equipped with floats may be used and the community would not need an airstrip on land. To accommodate the largest planes equipped with floats, a water area of 3000 feet would be necessary.

d. Community Services

An educational system is generally a minimal necessity in most rural locations and is used to provide traditional schooling and sometimes vocational training for the inhabitants of a community. Other community services such as police protection, fire protection, medical services, social services, and recreation may or may not be included in the development of a new community. The location of a community and the purposes to be served by its development would dictate the amount and extent of services required.

e. Land

The land requirement for a community of 200 homes depends upon the type of structures contemplated and the number and extent of other facilities which must be provided. The Alaska Remote Housing Program recommends a lot size of approximately 3000 square feet per home. The acreage needed for development of a community including 200 homes would be approximately 75 to 100 acres.

In summary, the resources or systems required for establishing and maintaining a community are

- Housing
- Public Utilities — Water supply and distribution, sewage collection and disposal, telephones, refuse collection and disposal, and electrical generation and distribution
- Transportation — Waterways, airports, and local roads
- Community Services — Education, safety, health, and recreation
- Land

3. Permits and Regulations

Coordination with state and federal agencies would be required for the construction of a new community. The Bureau of Land Management may require permits for rights-of-way for roadways, airstrips, and communication sites. Permits are required from the U.S. Environmental Protection Agency for disposal of solid and sanitary wastes. Air and water quality permits are required from the State of Alaska, Department of Environmental Conservation. Plan approval or permits may be required from, or at least given consideration by, the State of Alaska, Departments of Highways, Public Works, Education, Economic Development, Health and Social Services, Natural Resources, and Commerce and, if appropriate, federal agencies such as the Corps of Engineers, Soil Conservation Service, Public Health Service, and the Bureau of Indian Affairs.

4. Description of Action and Equipment

Basic engineering actions and equipment used are described in earlier sections on clearing and grubbing (Section IV.A), excavation (Section IV.B), construction filling on land (Section IV.C), foundation construction (Section IV.D), drilling for water (Section IV.G), and road construction (Section IV.I). The construction of an airport runway generally

employs a modification of roadway construction techniques. The size of operation and the duration of the project, however, can be expected to cover several acres and require a construction time of three to four years. Other considerations in community development and general actions undertaken in carrying out the construction activities are discussed below.

a. Site Selection

The location of the new community should minimally consider the following issues:

- Is the site available? An investigation into who owns the land is required.
- Is the site selected large enough to accommodate 200 homes? Consideration should be given not only to present needs, but also to future expansion.
- Is adequate water available? Does the site have a source of fresh water? Is the water safe to drink? What is the distance between the site and the source of water?
- Is the site subject to natural hazards or conditions affecting safety? Will the site be continually and adversely affected by flooding, storms, erosion, or other natural geologic occurrences?
- Will development of the site require use of special building techniques or site development procedures? Does the site drain well? Is there permafrost?
- Will development of the site have a significant and unavoidable adverse effect on the natural and physical environment of the area (i.e., air, water, terrestrial, and aquatic resources)?

Detailed investigation into such areas as soil and subsurface conditions, climate, erosion, accretion, faults, floods, vegetation and wildlife and, when appropriate, the subsistence harvest availability should be initiated. In addition, building materials and their distance from the site should be considered. Finally, the cost of establishing the community should be a major consideration.

b. Design and Construction

The construction methods currently used for rural housing in Alaska are based primarily on use of wood materials from rough logs to plywood. However, modular housing units and trailer homes may be used and would be transported to the site after fabrication. In addition to the foundation requirements for dwelling units, on-site development generally consists of the use of plywood for flooring, ceilings, and interior walls. For exterior use, plywood surfaces are also very frequently employed.

Permafrost conditions, earthquake intensity, and climatic elements have a considerable effect on the performance of buildings, and the diversity of their occurrence in Alaska would be reflected in the use of variable design techniques, based on local conditions. Design considerations which affect building performance include

- Continuous and discontinuous permafrost
- Frost heave
- Earthquake intensity
- Landslide potential
- Flooding
- Wildfire
- Winter temperatures
- Heating degree days
- Rainfall intensity and amount
- Snow loads
- Wind loads

Permafrost protection may be obtained by lifting the building about 2 feet above the ground level for needed cold air passage. Posts, pilings, skids, planks, and blocks are utilized to lift structures. In some cases, insulation pads of gravel and other materials are used to protect permafrost. Other methods which prevent permafrost damage include building in areas with well-drained coarse soils (close to rivers) or on well-drained coarse south-facing slopes where there is less chance of permafrost occurring. Avoiding permafrost areas is recommended in areas of discontinuous permafrost.

Earthquake protection is obtained by use of carefully braced walls and piling foundations. The walls are braced either with diagonal braces, diagonal shiplap, or plywood used as sheathing or siding. Lateral stability is further obtained by compacting earth around the footings on the foundation posts. Joints between different size structures built together should be especially developed for horizontal motion. In general, development sites should be selected so risks from landslides or other natural geologic hazard are minimized.

There is generally no protection against flooding other than location outside of a flood-prone area or the establishment of flood control dams upstream of a development area. Flooding of the floor level of houses for some weeks every year is considered by many residents to be the price paid for living close to rivers; however, new housing developments are generally located in areas not subject to flooding. Floating houses or houses on stilts are not used because of ice hazards.

Of the many climatic factors which influence building design, cold winter temperatures are perhaps the most critical consideration in most areas of Alaska. Minimization of heat loss may require protection of building entrances, insulation of all exterior surfaces, use of thermal windows (double-paned), and siting so that the greatest length of the building follows the direction of the prevailing winds.

5. Impacts

a. Air Quality

The air quality impacts related to community development result mainly from area and line source emissions at an intermediate height near the surface. The pollution distribution will affect larger areas than recreational development (Section IV.O) because of the areal extent of the source and the higher effective emission height. Impacts should be more localized, however, than impacts from stack emissions which generally characterize emissions from industries associated with natural resource development complexes (Section IV.P). The air quality in any community is a result of the intensity and spatial distribution of human activity within the area and the extent to which regional meteorology and topography enhance or inhibit pollutant dispersion. Regional meteorological characteristics (wind speed and direction, atmospheric turbulence, mixing layer height, and solar radiation) and topographical characteristics, including the character of the artificial topography created by man-made structures, influence the transport and dispersion of pollutant emissions and the ultimate air quality.

Simulation models have been developed to describe the transport and dispersion of pollutants. The models use meteorological conditions and pollutant emissions as input and yield as output estimates of pollutant concentrations. Much of the research, proposed or in progress, into the relationships between proposed community spatial structure and air quality centers around such models. The primary problem in using these models for planning is in the development of a reasonable and complete inventory of emissions (Roberts, et al, 1975).

Community development involves housing, streets, schools, government buildings, airports, utilities, commercial and service facilities, and recreation and community facilities, but communities generally are intimately related to the source of work for people.

This employment source is most often related to natural resource development: oil or mineral extraction or refining, food processing, fishing, or wood processing. Other centers of employment include transportation, government, military, education, or the tourist industry. The particular "industry" that forms the central reason for community development may also contribute significantly to the pollution emissions.

The estimation of emissions is a function of the fuels used; spatial distribution of the housing requirements which determine insulation used; environmental factors which determine the power consumption (such as temperature, hours of darkness, and type of industrial development); and the planning aims, goals, and regulations for enforcing energy conservation and pollution control. Important considerations in community development that would minimize both energy consumption and air quality impact include the use of centralized heating (perhaps using the waste heat from power generation), minimizing surface area to minimize heat loss, use of adequate noise and thermal insulation, and minimizing transportation requirements in winter. Planning choices based on energy conservation and air quality can make a significant difference, as shown in the estimated emissions from different housing patterns given in Table IV-XXVI, based on natural gas use and midlatitude heating requirements. Extrapolated to Alaska conditions, the savings are even more dramatic.

In spite of the difficulties in giving numerical estimates of emissions, the major sources of emissions can be identified for community development. Space heating represents one of the most widespread sources of emissions since most existing communities are set up so that each house or building has its own source of heat (wood stove, coal, oil or gas furnace, or electric heaters, in decreasing order of pollution emissions). The pollutants emitted include particulates, sulfur oxides, carbon monoxide, hydrocarbons, and nitrogen oxides. The effective height of emission is generally above the rooftops, so that there is some transport away from the source. For those sources that emit particulates, discoloration of snow may be important, and sulfur dioxide emissions may be of critical importance in areas where lichens are prevalent.

Power plants represent one of the largest emission sources in a community. They provide electricity for lighting, telephones, communications, and often heating. They burn coal, residual or distillate oil, and occasionally diesel oil and gasoline. Their pollutants are generally released from a tall stack, which means that the primary impact area is usually some distance downwind. If the site is well chosen with respect to meteorological variables, the impact on the community itself may be minimized. Power plants may also put out waste heat if they require cooling ponds, which often release heat and water vapor to the atmosphere and river systems.

Solid waste disposal in a community contributes as much as 9.7 percent of the total air pollution by mass. The practice of incineration is most commonly used, but

TABLE IV-XXVI. NEIGHBORHOOD COST ANALYSIS, AIR POLLUTION

	Housing Pattern (1000 Units)					
	A	B	C	D	E	F
	Single-Family Convention	Single-Family Clustered	Townhouse Clustered	Walk-up Apartment	High-Rise Apartment	Housing Mix (20% each A thru E)
Pollutants from Residential Natural Gas Consumption (pounds per day)*						
Particulates	14.27	14.27	9.56	7.42	6.48	10.40
SO _x	0.48	0.48	0.32	0.25	0.22	0.35
CO	0.32	0.32	0.21	0.16	0.14	0.23
HC	31.72	31.72	21.24	16.48	14.40	23.11
NO _x	95.16	95.16	63.72	49.44	43.20	69.34

* Assumes 67% of dwelling units use natural gas for heating, water heating, cooking, and clothes drying; 33% use no natural gas. No pollution effects of electricity use are calculated, as the location of the power plant is assumed to be external to the neighborhood.

Source: Real Estate Research Corporation, 1974

new sanitary landfill techniques and disposal/recovery technologies have been developed that reduce the atmospheric emissions. Carbon monoxide, hydrocarbons, and particulates are the primary pollutants emitted, but sulfur oxides and nitrogen oxides may be sufficiently plentiful to provide problems to sensitive organisms.

Transportation represents an important source of pollution, particularly in Alaska. Carbon monoxide and ice fog are two pollutants that are directly related to transportation sources. Emission rates for cars, trucks, and other vehicles were shown in Table IV-XIV, and emissions from airplanes were given in Table IV-X. Where meteorological conditions are favorable, carbon monoxide levels can build up, which currently occurs in Fairbanks, with fewer cars than in larger cities.

The industrial development that is generally the motivating force for the community development will itself put out air contaminants. Since these industries may vary and since the emissions are widely dissimilar, they are only indicated here as a major problem and are discussed in more detail in the section on natural resource development complex (Section IV.P).

Construction of the community will result in atmospheric emissions. These are discussed in the basic engineering actions and in complex actions such as road construction. The emissions include fugitive dust and gaseous emissions from the equipment used, and emissions associated with any base camps that are necessary for the workers.

b. Noise

Primary noise sources associated with the described community development include short-term construction-related impacts and long-term traffic and aircraft impacts. Construction noise levels for various types of structures and facilities are shown in Table IV-XXVII, as measured at 50 feet. Construction noise which occurs within a community after it is inhabited can create greater impacts due to the increased number of people exposed.

Traffic noise and noise from aircraft operations represent the most prevalent long-term sources of intrusion in most small communities. In addition, planning for placement of other potential noise sources (industrial or commercial facilities) can protect the community from land use conflicts. Many communities have adopted regulatory measures governing the intensity of land use, control limits on sound producing devices, and sound reduction engineering and architectural design requirements for transportation facilities and certain other forms of land use.

People generally have little or no knowledge of the possible effects that various types of installations can have on their environment until the conditions are

TABLE IV-XXVII. TYPICAL AVERAGE NOISE LEVELS AT
CONSTRUCTION SITES ASSOCIATED WITH COMMUNITY DEVELOPMENT*

Phase	Levels in dBA for							
	Housing		Offices, Schools, and Public Works		Recreation Facilities and Service Stations		Roads, Airfields, and Sewers	
	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site	All Pertinent Equipment Present at Site	Minimum Required Equipment Present at Site
Ground Clearing	83	83	84	84	84	83	84	84
Excavation	88	75	89	79	89	71	88	78
Foundations	81	81	78	78	77	77	88	88
Erection	81	65	87	75	84	72	79	78
Finishing	88	72	89	75	89	74	84	84

* 50 dBA ambient

Source: Bolt, Beranek, and Newman, 1971a

experienced, and then it is often too late. Therefore, it is important that the planning profession be sufficiently informed on all environmental considerations, so that these are taken into account prior to development. Land use controls, density controls, public property acquisition, and building code requirements for construction in undeveloped areas near highways and airports can be employed as defensive measures against noise intrusion. Preventive measures, however unpopular, are far less costly and difficult than corrective actions.

In response to noise problems, the enactment of city noise ordinances increased 23 percent between 1974 and 1975 (Bragdon, 1976). In Alaska, both Anchorage and Juneau have enacted legislation setting quantitative noise emission limits. Land use regulation through the zoning process is the largest single category of noise control. Table IV-XXVIII shows typical noise limits currently used in such land use regulations.

TABLE IV-XXVIII. TYPICAL COMMUNITY NOISE LEVELS ESTABLISHED BY ZONING ORDINANCE

Land Use Category	Permissible Noise Levels (in dBA)	
	Day 7:00 am to 10:00 pm	Night 10:00 pm to 7:00 am
Residential	55	40 – 45
Commercial	60	50 – 55
Industrial	70	60 – 70

Source: Bragdon, 1973

The noise levels which result from nonstationary sources (transportation) must be determined by use of such models as discussed in the section on general impacts of noise (Section II.B). Motor vehicle noise limits for autos and trucks can also be used to prevent operation of excessively noisy equipment. Such limits already have been established by the Environmental Protection Agency for motor carriers engaged in interstate commerce and many states and municipalities have adopted similar limits for motor vehicles. Aircraft noise levels are governed by the Federal Aviation Administration; however, the composite noise levels around communities can best be handled by planning and placement of airport facilities to avoid use conflicts.

c. Water Resources

Water quality is vulnerable to degradation from the massive construction effort, the greatest problem being from surface runoff by suspended silts, clays, and organic materials. Local water bodies would show increases in turbidity, sediment deposition, biochemical oxygen demand, and other contaminants to varying degrees as a result of clearing and grubbing, excavation, filling, spoil disposal, and road construction. Water quality degradation can be expected to continue following construction of the community and its support facilities, with contaminants from sewage treatment plant discharges, despite adherence to current Environmental Protection Agency discharge requirements. Long-term turbidity increases would be expected in surface waters from surface runoff from adjoining developments and storm sewer discharges. Short-term discharges of toxic or other deleterious substances such pesticides, heavy metals, fuel, and lubricants will also degrade present water quality. These substances would have adverse effects on the fishery resources present in the water bodies, which would also be adversely affected by increased human activity. (See Aquatic Biology for impacts of community development.) Increased soil imperviousness from structures and streets has the effect of increasing flood peaks during storm periods and decreasing low flows between storms.

d. Terrestrial Biology

Initial community development requires varied and extensive engineering actions, each resulting in specific impacts to the terrestrial ecosystem. These engineering actions include clearing and grubbing (Section IV.A), excavation (Section IV.B), construction filling on land (Section IV.C), foundation construction (Section IV.D), road construction (Section IV.I), and in many cases agriculture (Section IV.M). The impacts of each of these engineering actions on terrestrial communities have been described under their respective sections.

Additional impacts of considerable importance on terrestrial communities are those stemming from high human population concentrations and include atmospheric, solid waste, and noise pollution. The general effect that these factors have on plants and animals has been described in Sections II.D.3, II.D.5, and II.D.6. Changes in the quality and quantity of water (see discussion on stormwater runoff and sewerage, Section IV.N.5.g), soil (see discussion on erosion and sedimentation, mass wasting, subsidence, and permafrost, Section IV.N.5.f), and noise (see Table IV-XXVIII) may be expected. Substantial increases in all of these factors will reduce the total plant and animal species within the community and in the surrounding area. Increasing human population intensifies the impact upon the ecological systems which form the landscape. Man/wildlife interaction will increase directly through hunting and indirectly through competition for habitat and food. Man's interaction is exemplified by the common brown/grizzly bear/hunter interactions at streams and in campgrounds, and the moose/human interactions at community fringes. In both cases, wildlife suffers.

The introduction of nonnative animals (e.g., rats, mice, dogs, cats) and plant species (e.g., numerous weeds) frequently results in detrimental effects to native species. The impacts of some of these have been discussed in *Natural Hazards in the Alaska Environment: Processes and Effects*, Chapter VIII (1975), and in this document in Section II.D.1.

e. Aquatic Biology

The impacts for the basic engineering actions required for site development have been discussed earlier. The primary additional impacts are due to human use of the developed area. Depending on the sewage treatment system, various amounts of nutrients may be contributed to nearby aquatic systems and may affect them, as described in Section II.E.6. Paved streets or other surfaced areas (like roads) accumulate pollutants such as metals, petroleum combustion products, suspended sediment, and coliform bacteria, which are conducted to water systems in stormwater runoff. These materials may lower productivity in lakes or streams, as discussed in Sections II.E.2, II.E.6, and II.E.7. Additional human activity also could result in increases in subsistence, commercial, and sport fishing, which would require additional harvest limitations to ensure an adequate escapement for reproduction.

f. Soils

Those impacts described under clearing and grubbing, road construction, foundation construction, excavation, and drilling for water also apply to community development. Additional impacts are as follows.

(1) Erosion and Sedimentation — Community development, particularly during construction phases, has been documented to be highly susceptible to erosion and subsequent sedimentation. The amount of sediment and erosion resulting is greater than that resulting from any of the basic engineering actions, or the sum of the separate actions. Quantities and effects of this increased erosion and sediment are discussed more fully in Section IV.N.5.g, Interactions.

(2) Mass Wasting — Mass wasting hazards have been identified under the basic engineering actions. In addition, community development on unstable slopes can add structural weight to the slope, which can further increase mass wasting potential. Surface runoff from areas where development occurs tends to be moved to adjacent areas due to imperviousness of the surface. The additional volumes of water in adjacent areas may be a factor in initiating mass wasting.

(3) Subsidence — Structures placed on unsuitable soils, particularly high bulk organic soils, will lead to subsidence. Structures placed on fills over such soils can also

initiate or aggravate subsidence. Soils having shrink/swell properties related to temperature or moisture contract and expand periodically, and are apt to cause structural damage. Structures placed on soils susceptible to frost heave contract and expand seasonally and can also cause structural damage. Typical mitigating measures include replacement of frost-sensitive soil, chemical treatment of soil, placing of structures on pilings, or avoiding such soils by siting on well-drained coarse soils on southern exposures. Subsidence in permafrost areas is discussed in the following paragraph.

(4) Permafrost — Community development in areas of permafrost, particularly in fine-grained ice-rich soils, will result in subsidence. Engineering procedures such as insulating with gravel or placing structures on pillars can mitigate the effects and the occurrence of subsidence, but it will be very difficult for the residents of a 200-unit community to not disturb the vegetation of areas adjacent to the site; consequently, subsidence and erosion in these areas may occur. The degree of subsidence and erosion will depend on the care the individuals of the community display in not disturbing the thermal equilibrium of the area, and on the site-specific types of soils, depth to permafrost, and slopes in the vicinity.

(5) Covering of Soil with Impervious Material — Community development will result in covering of from 50 to 75 percent of the soils of the site with impervious material, essentially removing these soils from active participation in the area's ecosystem. The soils so covered are no longer biologically productive.

g. Interactions

Those interaction impacts described for all the basic engineering actions, including road building, are applicable to community development. Impacts specific to community development are discussed below.

(1) Sedimentation — Although sediment transfer has been discussed earlier for the basic engineering actions, the amount of sediment generated in community development is greater than any single action or the sum of the separate actions. Typical quantities of sediment transferred from the site of construction during development years were reported by the Real Estate Research Corporation (1972) and are shown in Table IV-XXIX. The amount of erosion (sediment transfer) depends on runoff, soil type, slope, mitigating measures taken during the construction period, and the type of development. However, the table provides an indication of sediment quantities characteristic of various residential units. Erosion and subsequent sediment transfer may cause reduction of spawning habitat, increased oxygen demand, alteration in benthic community, increased turbidity, increased nutrients in aquatic environments, and decreased soil resources and productivity in terrestrial environments.

TABLE IV-XXIX. ESTIMATED SEDIMENT
GENERATION FROM DIFFERING HOUSING PATTERNS*

	<u>Annual Average Volume During Development Period (tons/year)</u>
Single-family, conventional	119.5
Single-family, clustered	85.34
Townhouse, clustered	56.4
Walk-up apartments	40.8
High-rise apartments	23.2
Housing mix (20 percent each of above)	65.1

* Extrapolated from data based on 1000 units. Real Estate
Research Corporation, 1974, p. 72.

(2) Stormwater Runoff — Community development may impose various amounts of impervious surface on the area developed. These impervious surfaces can reduce the infiltration capacity of the developed area and result in increased discharge of stormwater from the site. In addition, the water quality makeup of the stormwater runoff differs markedly from that of the site prior to development. Typically, stormwater runoff has much higher concentrations of biological oxygen demand, chemical oxygen demand, nitrogen compounds, phosphorous compounds, suspended sediments, and fecal coliform bacteria, as indicated in Table IV-XXX. One should note these are "average" concentrations that can vary markedly, depending on precipitation and other factors. Table IV-XXXI presents characteristic volumes of runoff in liters per year from five different development types, given 40 inches of precipitation. Stormwater discharge will vary considerably, depending on porosity of the soil, slope, depth to impervious layer, mitigating measures, and degree of soil saturation.

The constituents identified as characteristic of stormwater runoff can have deleterious effects on aquatic systems. The biological and chemical oxygen demands can deplete dissolved oxygen in the receiving waters to an undesirable level. Nutrients

TABLE IV-XXX. TYPICAL CONSTITUENTS
CHARACTERISTIC OF STORMWATER RUNOFF IN URBAN AREAS

<u>Constituents</u>	<u>Quantity</u>
Biological oxygen demand (BOD)	0.0233 gram per liter
Chemical oxygen demand (COD)	0.0630 gram per liter
Nitrogen (N)	0.0027 gram per liter
Phosphorous (P)	0.0008 gram per liter
Suspended sediment (SS)	1.0000 gram per liter
Fecal coliform bacteria (FCB)	1216.0 number of bacteria per liter

Source: U.S. Department of the Interior, 1970

TABLE IV-XXXI. STORMWATER RUNOFF VOLUME
FROM VARIOUS TYPES OF COMMUNITY DEVELOPMENT*

	<u>Total Volume, Liters/Year</u>
Single-family, conventional	163,797,000
Single-family, clustered	121,305,000
Townhouse, clustered	91,836,000
Walk-up apartment	67,849,000
High-rise apartment	34,267,000
Housing mix (20 percent each of above)	95,262,000

* Extrapolated from data presented for 1000 units.
Real Estate Research Corporation, 1974, p. 72.

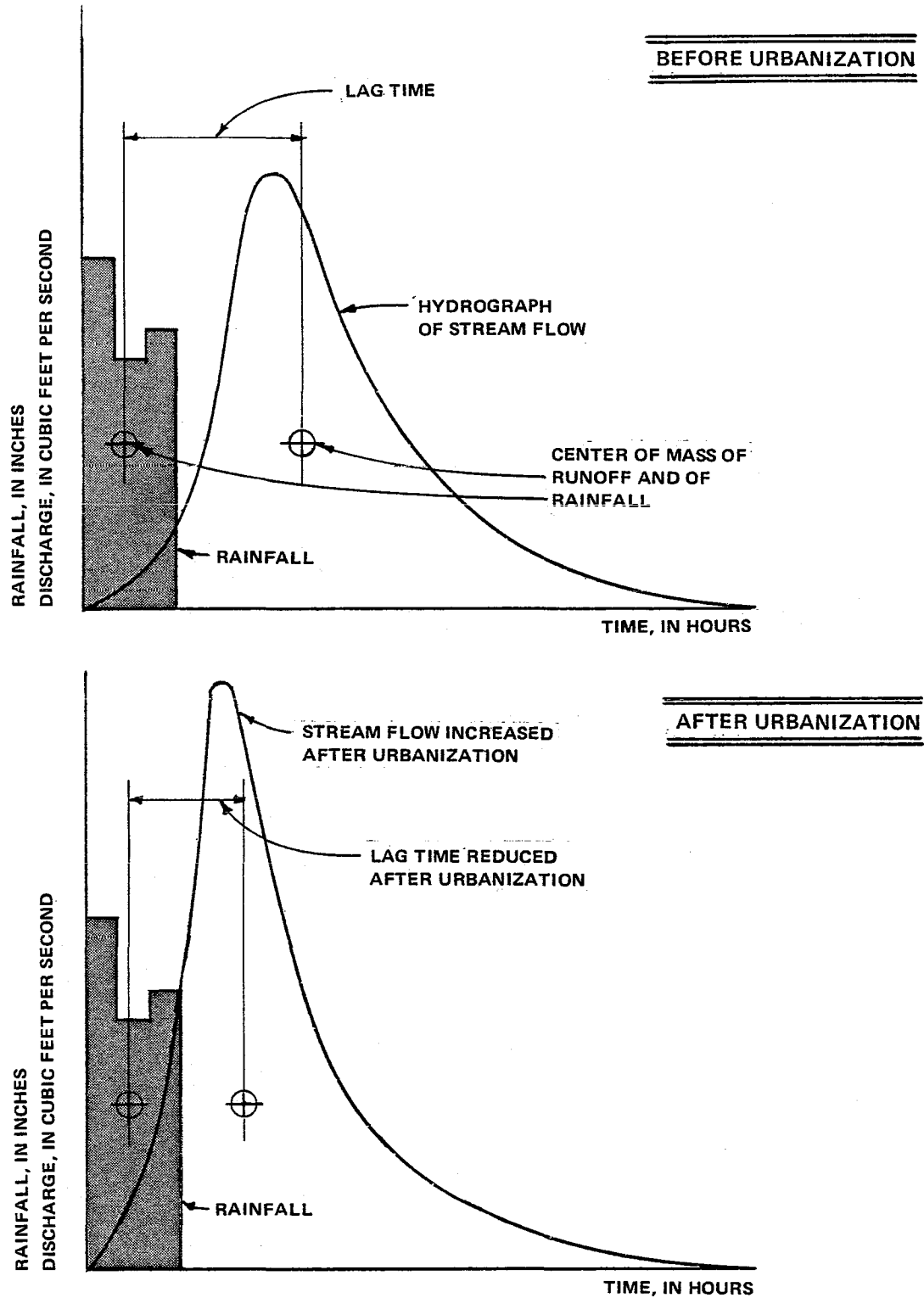
(nitrogen and phosphorous) can change the trophic structure and community composition of the receiving waters, which may or may not be desirable. Fecal coliform bacteria are an index to fecal contamination and their presence in receiving waters can be an indication of pathogens, which make the waters unusable as a water supply and unsafe for contact use (swimming).

Although stormwater runoff volume does increase in developed areas, the temporal pattern of discharge may be of more concern. Two aspects in the alteration of the discharge characteristics are presented in Figures 4-8 and 4-9. Figure 4-8 indicates the shorter lag time and the higher peaks of stream flow from an urbanized land surface condition than from a more pristine situation. Stream flooding and scouring are likely impacts of this pattern change.

Another change in the stream flow patterns in urban watersheds is illustrated by Figure 4-9. As can be seen, the curves associated with higher amounts of impervious surface (urbanized condition) are considerably steeper than the curve in the unurbanized area, indicating higher frequency of high flows and a greater variability of discharge. Also, the previously frequent low flows are decreased in number in an urbanized situation because low flows are not sustained by groundwater discharge as in an unurbanized basin.

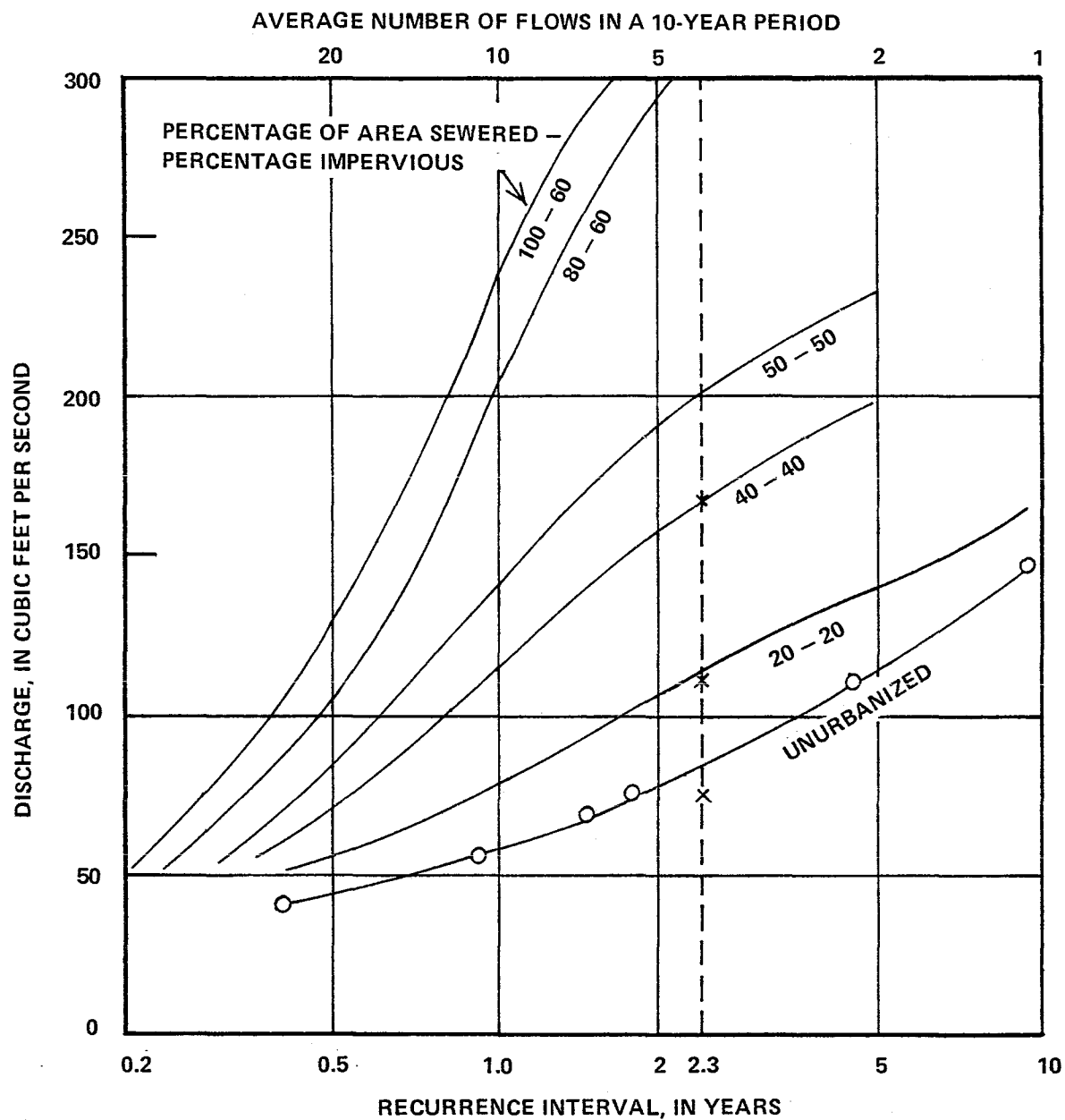
These changes in temporal patterns can cause flooding, instability of the streambed due to scouring and bank erosion, loss of suitable spawning habitat, and the possibility of seasonal loss of stream habitat by lower flows. In addition, higher temperatures with deleterious consequences on the biota of the aquatic systems can result from reduced flows.

(3) Sewerage — People generate an estimated 100 gallons (378.5 liters) of sewerage per person per day (Seelye, 1968). The effluent is comprised of 99.9 percent water and 0.02 to 0.04 percent solids. Of the solids, 40 to 50 percent are proteins, 40 to 50 percent are carbohydrates, and 5 to 10 percent are fats. This sewerage can be deposited untreated at a local convenient environment (e.g., septic tanks, and raw effluent into receiving waters), or the sewerage can be collected and receive some degree of treatment prior to introduction into local environments. The effluent releases nutrients, toxicants, and unstable organic and inorganic materials to local environments. The concentration of pollutants depends on treatment as indicated by Table IV-XXXII. Even with tertiary treatment, considerable amounts of these constituents remain as indicated in Table IV-XXXIII and can have deleterious effects on receiving waters. The effects of sewerage vary according to disposal method. Three modes of disposal are discussed below, together with the associated impacts.



Source: Leopold, 1972

Figure 4-8. Hypothetical Unit Hydrographs Relating Stream Runoff to Rainfall



Source: Leopold, 1972

Figure 4-9. Flood-Frequency Curves Characteristic of a One-Square-Mile Basin in Various States of Urbanization.

TABLE IV-XXXII. PURIFICATION OF
RAW SEWAGE BY TREATMENT PROCESSES

Process	Approximate Percentage of Reduction		
	Five-Day BOD	Suspended Solids	Bacteria
Plain sedimentation	30 – 40	40 – 75	25 – 75
Septic tank	25 – 65	40 – 75	40 – 75
Chemical precipitation	60 – 75	70 – 90	40 – 80
Sedimentation + contact beds	50 – 75	70 – 80	50 – 80
Sedimentation + trickling filters (low-rate)	80 – 90*	80 – 90*	90 – 95
Sedimentation + activated sludge	85 – 95*	85 – 95*	90 – 98
Sedimentation + intermittent slow sand filters	90 – 95*	85 – 95*	95 – 98
Oxidation ponds	75 – 95**	***	> 99.9

* Even higher reductions are sometimes attained.

** BOD after filtration.

*** Suspended solids may be high because of presence of algae.

Source: Klein, 1966

TABLE IV-XXXIII. CONSTITUENT QUANTITIES
FROM SEWERAGE EFFLUENT WITH TERTIARY TREATMENT,
LIME CLARIFICATION, AND MULTIMEDIA FILTRATION

<u>Constituent</u>	<u>Quantity</u>
Biochemical oxygen demand (BOD)	0.005 gram per liter
Chemical oxygen demand (COD)	0.042 gram per liter
Nitrogen (N)	0.017 gram per liter
Phosphorous (P)	0.001 gram per liter
Suspended sediment (SS)	0.002 gram per liter
Fecal coliform bacteria (FCB)	100% removal

Source: Real Estate Research Corporation, 1974

(a) Septic Tanks — Soils have an intrinsic suitability for the harboring of septic tanks. Of particular significance is the porosity of the soil, slope, depth to groundwater, depth to bedrock or the impervious layer, and annual soil freeze. Even suitable soils have a saturation point and can only absorb a limited density of septic tanks. Septic tank densities beyond this level will result in a transfer of their constituents to surrounding environments, particularly surface waters and groundwater. Small lakes, wetlands, and areas with high groundwater table are particularly prone to contamination. Impact of such contamination may be the introduction of pathogens into a water supply, unpleasant odors in the local environment, and an increase in nutrient transfer to adjacent waters, possibly resulting in eutrophication and changes in trophic structure and community composition.

(b) Raw Sewerage — The effects of releasing raw sewerage to receiving waters depend on a number of factors reflected in the assimilative capacity of the receiving waters and the amount of sewerage released. Small shallow lakes are least able to receive waste material without drastic changes in water quality and structure of the biotic community. Large deep rivers and marine areas with strong tidal influence are more able to receive effluent without drastic undesirable changes in their character. Ice cover reduces the assimilative capacity of the receiving waters by interfering with atmospheric gaseous exchange. Consequently, anaerobic conditions can result.

The effects of releasing BOD and COD under surface ice conditions would be more severe and be felt further downriver than in similar receiving waters without surface ice. The length of the "septic zone" would be seasonally increased. Fecal constituents of raw sewerage can introduce pathogens into receiving waters. Sewerage contamination of water supply has led to epidemics in cholera, typhoid, and dysentery. The occurrence of fecal contamination of water is measured by the presence of *Escherichia coli*, a harmless coliform bacteria which is easily cultured and used as an indicator.

(c) Treated Effluent — The effects of treated effluent are similar to those identified for raw sewerage, only less severe. Table IV-XXXII indicated to what degree different treatment processes remove waste. In addition, treatment usually removes pathogens from the effluent.

(4) Solid Waste — An estimated 2555 pounds per person of solid waste is generated annually (Flawn, et al, 1972). The composition of this material is shown in Figure 4-10. If one assumes 3.5 persons per housing unit, the amount generated for 200 units is nearly 900 tons per annum. Although technology is available for energy recovery from solid waste and for material recycling, the relatively small amounts generated by a 200-unit development would not support the establishment of an energy recovery system or recycling system. Given current costs and technology, the most probable solid waste disposal system would be sanitary landfill.

PERCENT BY WEIGHT				
NONCOM- BUSTIBLE	WASTE	GARBAGE		
	FOOD	FATS		
NONCOM- BUSTIBLE		METALS	GLASS AND CERAMICS	ASHES
		LEAVES, GRASS, BRUSH, WOOD	MATE- RIALS	STREET REFUSE
RUBBISH		RAGS, HOUSE DIRT, ETC.		
		PAPER		

Source: McHale, 1969

Figure 4-10. Average Composition of Municipal Refuse

The environmental impacts of a sanitary landfill depend on the hydrology, geology, and soils of the site; composition of the disposal material; and operation of the fill. A satisfactory site would have the following conditions:

- The site should be well above water table or zone of saturation.
- The permeability of the soil should be low enough to retard movement of contaminants such that contaminants produced would be unable to reach any groundwater reservoir, or would be reduced to an acceptable level prior to entering such a reservoir.
- The site should be positioned such that groundwater flow and leachate from the site are made acceptable prior to entering surface water bodies.
- The site should be selected in areas of geologic stability where fissures or fractures do not occur which may allow free accessibility of contaminants to groundwater reservoirs.

In most cases, sanitary landfills remain unstable in that they are subject to future subsidence and further decomposition. Therefore, they are generally unsuitable as sites for structures.

Cold temperatures characteristic of Alaska limit decomposition rates of the solid waste. Consequently leachate contaminants can be generated for essential periods of time and instability of the fill material may prevail indefinitely. Another problem peculiar to Alaska is the attraction of black bears and the more dangerous brown/grizzly bears to fill sites, which may endanger local inhabitants. Removal of nuisance bears or bearproofing disposal sites may be necessary. In addition, a sanitary landfill, if operated improperly, can attract and harbor rodents and insects which are potential reservoirs for disease vectors.

Sanitary landfill over permafrost areas could have particularly severe consequences. Removal of vegetation and the surface organic layer and replacement by compacted waste material will probably alter the heat budget of the site and result in an increase in the depth of the active layer and consequent subsidence. In turn, subsidence may be followed by the forming of a shallow anaerobic water body at the site.

(5) Synergistic Effects of Development — Environmental impacts tend to be synergistically interdependent. Frequently, the aggregate of several impacts is more severe than the sum of each impact considered separately. For example, a decrease in the pH of water increases the solubility of heavy metal salts in water. If acidic water interacts with soils containing heavy metal salts, the result is an increase in the heavy metals in the aquatic

system. Together the two factors of low pH and heavy metal ions can establish conditions more deleterious to biotic systems than each effect considered separately. This synergism is well documented in regards to water chemistry and toxicity, and is believed to apply to environmental impacts in general.

In another example, increased hunting pressure near human population centers may not result in reduction of local wildlife populations. However, increased hunting pressure, in conjunction with harrassment by pets, indiscriminate use of off-road vehicles, and increased mortalities due to road kills, may establish conditions which make an area unable to support a particular wildlife species. The total synergistic effect of replacing a predominantly natural system with human-oriented development may be impossible to project. However, such changes tend to be long-term in duration and are generally irreversible in nature.

IMPACT ANALYSIS, COMMUNITY DEVELOPMENT

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	2		3,4,5,6	1,2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a,b,c; 2a-e, j,k; 6	5,7	3,4	1,2,5,6,7 3a		4	2,3,5,7,8		9	2a 4a; 6b	3	
	CU	2		3,4,5,6	1,2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2,5,6,7 3a	1	4	2,3,5,7,8		9	2a 4a; 6b	3	
	SM	0																					
B. NORTHWEST	CL	2		3,4,5,6	1,2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	2,3,5,7,8		9	2a 4a	3 6b	
	CU	2		3,4,5,6	1,2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	2,3,4,7,8	5	9	2a 4a	3 6b	
	IL	0																					
	IU	1		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	2,3,4,7,8	5	9	2a 4a	3	
	SM	0																					
C. UPPER YUKON/ PORCUPINE	IL	1	1	3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a,b,c; 2a-e, j,k; 6	5,7	3,4	2,5,6 3a	1,7	4	5,7,8		2,3,9	2a 6b	3	4a
	IU	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2,5,6 3a	1,7	4	2,3,4,8	5		2a 4a	3 6b	
	SM	1			1,2,3,4,5	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7		2,5,6,7 3a	1		4,8	2,2,7		2a 4a	3	
D. TANANA	IL	1	1 2a,c,d	2b 3,4,5,6		1,5	1,cd 3a,b,c,d,e,f		1,2,3,5,6,7		4,8	1a,b,c; 2a-e, j,k; 6	5,7	3,4	3a 6	2,5	1,4,7	8		2,3,5,7,9	2a	3	4a
	IU	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	3a 6	1,2,5	4,7	8	2,3,4,7	9	2a	3 4a	
	SM	1			1,2,3,4,5	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7		8	2,3,4,7	9	2a	3 4a	
E. YUKON/KOYUKUK	IL	0																					
	IU	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	8	2,3,4,7	9	2a	3 4a	
	SM	1			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	8	2,3,4,7	9	2a	3 4a	
F. YUKON/ KUSKOKWIM DELTA	CL	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a,b,c; 2a-e, j,k; 6	5,7	3,4	1,2,5,6 3a	7	4	5,7,8	2,3	9	2a 6b	3 4a	
	CU	1			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	2,3,4,7,8		9	2a 4a	3	
	SM	1			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	2,3,4,7,8		9	2a 4a	3	
G. UPPER KUSKOKWIM	IL	1	1	3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	8		2,3,5,9	2a	3	4a
	IU	1		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	8	2,3,4,7	9	2a	3 4a	5a,c
	SM	0																					
H. COOK INLET	CL	1	1 2a,c	2b,d 3,4,5,6		1,5	1,cd 3a,b,c,d,e,f		1,2,3,5,6,7		4,8	1a,b,c; 2a-e, j,k; 6	5,7	3,4	3a	1,2	4,5,6,7	8		2,3,5,9		2a 3; 5a,c	4a
	CU	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	3a	1,2	4,5,6,7	8	2,3,4	9		2a; 3 4a; 5a,c	
	IL	0																					
	IU	0																					
	SM	2			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2 3a	5,7	1,4,6	4,8	2,3	9	2a	4a 5a,c	
I. COPPER RIVER	IL	2	1	3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2 3a		1,4,5,6,7	8	5	2,3,9		2a 3	4a
	IU	0																					
	SM	2			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7		4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2 3a	5,6,7	1,4	8	2,3,4	9	2a	4a 5a,c	
J. ALEUTIAN	CL	2			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,5,6,7	4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4		1,2,5,7 3a	4,8	8		2,3,5,9		2a; 3 5a,c	4a
	CU	2			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,5,6,7	4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4		1,2,5,7 3a	4,8	4,8	2,3	9	6b	2a; 3 4a; 5a,c	
	SM	2			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,5,6,7	4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2	3a 5,6,7	1,4	4,8	2,3	9	6b	2a; 3 4a; 5a,c	5a
K. BRISTOL BAY	CL	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7	4,8		1a,b,c; 2a-e, j,k; 6	5,7	3,4	1,2,5,6 3a	7	4		2,3,5,9	2a	3	4a 5a,c	
	CU	2			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f	1,2,3,5,6,7	4,8		1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2,5,6 3a	7	4	4,8	2,3	9	2a	3 4a	5a,c
	SM	0																					
L. KODIAK/SHELIKOF	CU	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,5,6,7	4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2	3a 5,7	1,4,6	4,8	2,3	9	6b	2a; 3 4a; 5a,c	
	SM	1			1,2,3,4,5,6	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,5,6,7	4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2	3a 5,6,7	1,4	4,8	2,3	9	6b	2a; 3 4a; 5a,c	
M. GULF OF ALASKA	CL/ CU	2		1,2,3,4,5,6		1,5	1,cd 3a,b,c,d,e,f			1,2,3,4 5,6,7,8		1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2	5,7	3a 4,6	2,3,4,8		9		2a; 3 4a; 5a,c	
	SM	2		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,5,6,7	4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2	1,5,7 3a	4,6	4,8	2,3	9	6b	2a; 3 4a; 5a,c	
N. SOUTHEAST	CL	1		1,3,4,5,6	2	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,4 5,6,7,8		1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2	5,7	3a 4,6	8		2,3,5,9	6b	2a; 3 5a,c	4a
	CU	1		1,2,3,4,5,6		1,5	1,cd 3a,b,c,d,e,f			1,2,3,4 5,6,7,8		1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	1,2	5,7	3a 4,6	2,3,4,8		9	6b	2a; 3 4a; 5a,c	
	SM	2		3,4,5,6	1,2	1,5	3a	1,cd 3b,c,d,e,f		1,2,3,5,6,7	4,8	1a	1,b,c; 2a-e, j,k; 5; 6; 7	3,4	2	1,7 3a	4,5,6	2,3,4,8		9	6b	2a; 3 4a; 5a,c	

O. RECREATIONAL DEVELOPMENT

1. Introduction

Recreational facilities are constructed to provide views of outstanding natural attractions; an opportunity for relaxed appreciation of nature; food, shelter, or other services to visitors; and a focal point for the pursuit of such recreational activities as hunting, fishing, hiking, canoeing, camping, etc. Each facility can be expected to be provided access by aircraft, passenger boat, roadways, or a combination of each.

The areas served by these recreational facilities are usually selected on the basis of their environmental sensitivity, since each may be utilized for intensive recreation, low-density recreation, or wilderness. Areas intended for intensive recreation include access facilities, campgrounds, interpretive centers, picnic grounds, lodges, boating facilities, and other areas which generate high activity or participation levels. Low-density recreation areas are often buffers to the wilderness areas and are intended for lower participation levels and recreation pursuits of a passive nature. Opportunities often provided within this classification are hiking and cross-country skiing, isolated fishing, occasional camping, hike-in camping, and nature study. Wilderness areas are characterized by limited access and a lack of development in order to maintain natural settings and habitats.

Alaska's tourism is increasing at a rate of 15 percent annually and is one of the state's three major industries. The demand for recreational facilities, though not in direct proportion to tourism, can also be expected to increase. It can also be expected that tourism will be encouraged by private and public interests to support recreational use of areas and counteract political and economic interests hostile to restricted land use.

2. Resources Required to Complete Action

In addition to labor and equipment, access and water supply are the primary requirements for the construction of recreational facilities, including lodges, motels, hotels, offices, warehouses, maintenance facilities, employee housing, campgrounds, picnic areas, shelters, and interpretive centers. Resources for site development, access, and water supply are described in discussions on clearing and grubbing, excavation, construction filling on land, foundation and road construction, and drilling for water. Resource requirements for airports are similar to those for road construction, and access by passenger boats may require resources described under the dredging discussion.

3. Permits and Regulations

Coordination with state and federal agencies is required for the construction of a new recreation facility. The Bureau of Land Management may require permits for

rights-of-way for road construction, airstrips, and communication sites. Permits are also required from the Environmental Protection Agency for disposal of solid and sanitary wastes. Air and water quality permits are required from the Alaska Department of Environmental Conservation. Plan approval or permits may be required from, or at least given consideration by, the Alaska Departments of Highways, Public Works, Education, Economic Development, Health and Social Services, Natural Resources, and Commerce and, if appropriate, federal agencies such as the Corps of Engineers, Soil Conservation Service, Public Health Service, and Bureau of Indian Affairs.

4. Description of Action and Equipment

Description of actions and equipment used are addressed in earlier discussions on clearing and grubbing, excavation, construction filling on land, foundation construction, dredging, drilling for water, and road construction. The construction of an airport is a modification of roadway construction techniques.

5. Impacts

a. Air Quality

The air quality impacts associated with recreational development are for the most part local impacts. Increases in pollution concentrations are generally limited to the immediate areas around camping areas or lodges, or from various vehicles used in the pursuit of recreation. The impacts depend on the intensity of development and the seasonal distribution of the use of the areas. In most cases, recreational development will take place in areas that have extremely clean air. Total air quality impacts will have to be assessed based on the more stringent regulations provided to prevent significant deterioration of these areas.

The construction of recreational facilities may involve many of the basic engineering actions, particularly clearing and grubbing, and some more complex actions such as road building. All of these activities will result in fugitive dust emissions and gaseous emissions from vehicles used and pollution from open burning. An important source of emissions is the gaseous and particulate emissions from cars, trucks, all-terrain vehicles, snowmobiles, aircraft, and motorboats. These emissions are discussed in other sections of this report, but are most important because of the dust generated and the carbon monoxide and lead emitted into the atmosphere.

In general, most of the recreational use will be concentrated in the summer months when dispersion conditions are usually good but evaporation occurs rapidly, which can make dust a problem. The emission contributions of motorbikes and snowmobiles are becoming an increasing problem as people come to recreation centers and then use

motorized transport to carry them around scenic areas. In most cases, the pollutants are quickly dispersed and concentrations do not build up. During the winter, wind speeds in sheltered valleys and thick forests are significantly lower, dispersion times are long, and pollution may not disperse adequately. The only potential problem seems to be when persons using motorized transport use the same trails as persons who are hiking, skiing, backpacking, etc. Since these persons are often carrying packs and doing moderately strenuous exercise, the exposure to carbon monoxide can be a potential health problem at concentrations significantly less than the ambient standards.

Burning fuel for heat and cooking is another important source of emissions. Campfires and fireplaces generate pollutants similar to open burning, as discussed under clearing and grubbing (Section IV.A), but in much smaller quantities. Smoke from campfires and chimneys of lodges or cabins is often seen hanging in the air below the treetops in the early morning before warming by the sun breaks up the nocturnal temperature inversions. The quantity of pollutants emitted depends on the characteristics of the fuel (wood) burned. For example, green or moist wood gives out more smoke (particulates) and carbon monoxide because of the lower efficiency of combustion. Campers and trailers, which are becoming popular, use heaters and generators that burn kerosene, white gas, or gasoline and so may result in emissions more similar to the idling emissions of cars (13 to 16 grams of carbon monoxide per minute), depending on the size of the generator and the length of time it is used.

At more intensely developed areas, power generation is required to provide electricity, heat, or power for facilities such as ski tows, lighting, hot water, heat for cabins, staff housing, lodges, visitor centers, etc. There will be atmospheric pollutants emitted from such a facility. Waste disposal presents an ever-increasing problem, particularly as recreational use of areas increases. Before passage of recent laws and regulations, litter even from recreational uses was often encountered in wilderness areas. Current practice emphasizes packing out waste, burning in campfires, or burying the nonburnable materials. Where burning of waste is carried out, pollutants are emitted.

The most serious air pollution problem which may increase due to recreational development and use is the potential for man-caused wildfires. For this reason, the analysis of impacts from this type of development may be determined in part from information regarding climatic conditions and fire hazard potential. Emission factors for open burning are summarized in Table IV-XXIII. Fire hazard potential is discussed in more detail in *Natural Hazards in the Alaska Environment: Processes and Effects* (John Graham Company/Boeing Computer Services, Inc., 1975).

b. Noise

Noise levels associated with recreation facilities vary widely, depending on the intensity of the developed areas and the purpose to be served by the facility.

Low-density recreation areas generally exhibit a degree of solitude, free from intrusion and disruption, while high-density recreation areas often attract noise-producing activities and vehicles. The ambient noise environment of the area, expected recreational use of the area, and resulting noise levels associated with such uses must be considered in planning for recreation site development.

The typical ambient noise levels associated with various outdoor settings for use as recreation sites are shown in Table IV-XXXIV. Generally, the quieter the background level against which an intrusive noise is projected, the greater the distance over which the noise can be heard. Some typical activities associated with recreation areas and the average noise levels expected are shown in Table IV-XXXV.

Wilderness is legally defined, in part, as providing "outstanding opportunities for solitude" (U.S. Congress, 1964). A number of studies on wilderness use and users have demonstrated the importance of solitude (minimal contact between camping parties) as part of the wilderness experience. In a survey of 500 visitors to four wilderness areas, Stankey (1973) reported that "most visitors consider low intensities of use, involving only few encounters, as an important dimension of the wilderness experience." Hendee, et al (1968), Lucas (1973), and Burch and Wenger (1967) all found that a strong preference for solitude was expressed by "wilderness purists," in contrast to other park users.

High-intensity recreation areas require facilities which tend to encourage noisy activity such as boating and roadways or trails for motor vehicles. Recreation vehicles include pleasure boats, snowmobiles, all-terrain vehicles, and motorcycles. There has been a remarkable growth in the number of these vehicles in the last 20 years. The noise output of leisure vehicles, although dependent on speed, is primarily a function of the way they are operated. Though many off-road vehicles are capable of speeds of 80 to 100 miles per hour, they are often operated in the lower gears at medium to high engine output and near their maximum noise output. The levels of noise for recreation vehicles, as shown in Table IV-XXXV, are extremely high and equipment operators exposed to such high levels over time could suffer temporary or permanent hearing loss.

Few definitive studies have been conducted regarding the effects of intermittent high noise on wildlife. During environmentally stressful periods (e.g., molting, wintering, nesting), noise generated by off-road vehicles could be extremely disruptive and cause increased mortality and decreased reproduction. By contrast, in areas having a relatively continuous noise source (e.g., pumping stations, highways) wildlife may become accustomed to the disturbance and would not be as seriously affected. However, sporadic use of off-road vehicles would be considered disruptive, and most species would not become accustomed to such disturbance.

TABLE IV-XXXIV. TYPICAL AMBIENT NOISE
LEVELS OF VARIOUS POTENTIAL RECREATION SITES

<u>Setting</u>	<u>Noise Level (in dBA)</u>
Meadow	10
Woods	20
Lake and woods	20
Meadow with barrier	10
Stream and woods	30
Woods with barrier	20

Source: Dailey and Redman, 1975

TABLE IV-XXXV. NOISE LEVELS OF
TYPICAL RECREATION ACTIVITIES

<u>Noise Source</u>	<u>Noise Level at 50 Feet (in dBA)</u>
Trailbike motor	74
Safety whistle	76
Gunshot (30.06 rifle)	136 (dBC)
Chopping wood	64
Pounding tent stakes	66
Conversation (four people)	48
Singing (four people)	60
Outboard motor, 6 to 10 horsepower	70
Outboard motor, 10 to 50 horsepower	78
Outboard motor, 50+ horsepower	80 – 100
Snowmobiles (current production)	77 – 86
Snowmobiles (unmuffled)	90 – 95
Dune buggies and off-road vehicles	96

Sources: Dailey and Redman, 1975; Wyle, 1971

c. Water Resources

The chemical characteristics of surface waters for recreational use vary with location and utilization of the site. Low-density recreational facilities can be expected to increase the levels of coliform bacteria, as discussed in Section II.C.7, and the concentrations of phosphorus and nitrogen in the vicinity, as discussed in Section II.C.6. These effects can result from effluent of the common pit toilet leaching into surface waters near campsites. Shoreline activities at the sites, such as swimming, washing dishes, cleaning fish, boat launching, and seaplane use, are other probable causes.

In more intensive use areas, visitors can be expected to contribute to the natural nutrient budget of surface waters by addition of sanitary wastes, outboard motor wastes, detergents, and solid wastes. In addition, heavy campsite use may accelerate soil erosion through deterioration of vegetation and compaction (discussed in Section II.C.1) and can result in an increase in both nutrient contributions and suspended sediment. The effects created by the construction of recreational facilities, such as lodges, offices, warehouses, staff and maintenance facilities, providing water supply and access are discussed in earlier sections of the report and include clearing and grubbing, excavation, construction filling on land, foundation construction, drilling for water, and road construction.

d. Terrestrial Biology

Short- and long-range influences on the terrestrial environment result from recreational development. Clearing and grubbing, excavation, and road construction result in immediate short-range influences. These detrimental effects on terrestrial communities have been described in Sections IV.A, IV.B, and IV.I. Construction of recreational facilities, employee housing, campgrounds, picnic areas, shelters, interpretive centers, and access facilities (including airports and docks) will remove or alter vegetative communities and thereby influence the distribution and abundance of many wildlife species. Animals that have the ability to emigrate will leave the area, at least during actual construction. Small mammals, amphibians, and reptiles that are not mobile will succumb.

The long-range effects of recreational development are among the most serious with respect to adverse impacts on plant and animal communities. Intensive use areas will be sources of noise, air, solid waste, and some pesticide pollution. The effects of these influences on terrestrial organisms are discussed in Sections II.D.6, II.D.3, II.D.5, and II.D.4, respectively.

Human/wildlife interactions will increase. In fact, many recreation areas are the focal locations from which hunting activities take place. Game species composition and numbers will therefore vary with distance from the recreational site. Likewise, in those recreational areas where hunting is prohibited, a certain animal species may occur in higher

concentrations (e.g., bear, rodents) because of the ready availability of food. Feeding by humans and indirect supplements from discarded food and other wastes result in wildlife populations that are pests and have to be destroyed. Clearly, it is the type of recreational facility, and its location, usage, and upkeep, that will determine the long-range impacts of the facility on plants and wildlife.

e. Aquatic Biology

Impacts of recreational development on aquatic life will vary, depending on the intensity of development. Wilderness areas are the least developed for recreational activities and impacts are minimal. Some nutrients from human waste would be contributed to local water systems and in heavily used areas could result in some short-term impacts, as described in Section II.E.6. As the intensity of development increases, erosion from campsites and parking areas would be expected to introduce impacts associated with silt and turbidity, as discussed in Section II.E.1. In areas of heaviest use, increased fishing pressure could impact fish populations, as discussed in Section II.E.7, and the effects of nutrient input to water systems (Section II.E.6) would increase. Insecticides and herbicides used to control pest species could affect aquatic species, as described in Section II.E.2.

f. Soils

Those impacts previously identified as resulting from clearing and grubbing, foundation construction, and possibly road construction are applicable to recreational development. In addition, recreational developments can concentrate people in areas where previous use was extremely light. Heavy use in these remote areas can result in destruction of fragile vegetation through trampling. Trail systems, if ill designed, can channel surface water and cause gully erosion. Poorly drained steep slopes, areas of permafrost, and soils in alpine environments tend to be particularly sensitive. Excessive use of an area destroys vegetation, compacts soil, and frequently leads to erosion and further habitat destruction. This damage is especially noticable in areas that receive heavy use from all-terrain vehicles. Similar impacts may occur in fragile wilderness areas (e.g., alpine meadows) that receive heavy horse and backpacking use. Destruction of plant communities and subsequent erosion and deterioration of sites are again the result.

g. Interactions

Recreational development imposes impacts identified previously under clearing and grubbing, excavation, foundation construction, and road construction (Sections IV.A, IV.D, and IV.I). Some of the impacts identified under community development (Section IV.N) may also be applicable to recreational development. However, these impacts are expected to be less severe. Recreational developments, by their nature, may increase use in areas previously lightly used, thereby increasing wildlife/people encounters. The effect of

human activity on wildlife is a function of both species and season; however, the animals will have to behaviorly adjust or emigrate from the area. Moose, for example, can adapt to the presence of humans, whereas bear (black and brown/grizzly) can be aggressive (Erickson, 1965).

IMPACT ANALYSIS, RECREATIONAL DEVELOPMENT

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7 3a		4,5		2,3,7	5	6b	2a 4a	2c
	CU	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7 3a		4,5		2,3,7	5	4a	2a,c	6b
	SM	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7 3a		4,5			2,3,7	4a		2a,c
B. NORTHWEST	CL	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7 3a		4,5		2,3,7	5		2a 4a; 6b	2c
	CU	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7		4,5		2,3,7	5	4a	2a	2c 6b
	IL	0																					
	IU	1		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7		4,5		2,3,7	5			2a,c 4a; 5a
	SM	0																					
C. UPPER YUKON/ PORCUPINE	IL	2	1		2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k 3,5		1,2,6,7 3a		4,5		7	2,3,5	6b	2c	2a 4a; 5a
	IU	2		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5		2,3,7		4a	2a 6b	2c 5a
	SM	2			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5			2,3,7	4a	2a,c	
D. TANANA	IL	2	1 2a,c,d	2b 3	4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5			2,3,5,7		2c	2a 4a; 5a
	IU	2		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5		2,3	7		2c 4a; 6b	2a 5a
	SM	2		3	1,2,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5			2,3,7	4a	2c	2a
E. YUKON/KOYUKUK	IL	2	1		2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5		7	2,3,5		2c 6b	2a 4a; 5a
	IU	0																					
	SM	2			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5			2,3,7	4a	2c	2a
F. YUKON/ KUSKOKWIM DELTA	CL	1		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5		2,3,7		6b	2c 4a	2a
	CU	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5		2,3,7			2c 4a	2a
	SM	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2a,ab,ijk	3,5	7	1,2,6 3a	4,5		2,3			2a,c 4a	
G. UPPER KUSKOKWIM	IL	0																					
	IU	0																					
	SM	2			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2,1k	3,5	1,2,6,7 3a		4,5			2,3,7	4a	2c	2a
H. COOK INLET	CL	2	1 2a,c	2b,d 3	4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2a,ab,ijk	3,5	1,2,6,7 3a		4,5			2,3		2c	2a 4a; 5a
	CU	2		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2a,ab,ijk	3,5	1,2,6,7 3a		4,5		2,3			2c 4a	2a 5a
	IL	2	1		2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2a,ab,ijk	3,5	1,2,6,7 3a		4,5			2,3,7		2c 4a	2a 5a
	IU	0																					
	SM	2		3	1,2,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	2a,ab,ijk	3,5	1,2,6,7 3a		4,5		2,3			2a,c 4a	
I. COPPER RIVER	IL	1	1		2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7 3a		4,5		7	2,3,5		2a,c 4a	5a
	IU	0																					
	SM	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f	1,2,3,6,7		4,5,8	1abc 2cd,ijk	3,5		1,2,6,7 3a		4,5		2,3	7		2a,c 4a	
J. ALEUTIAN	CL	0																					
	CU	0																					
	SM	0																					
K. BRISTOL BAY	CL	1		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f		1,2,3,6,7	4,5,8	1abc 2cd,ijk	3,5	7	1,2,6 3a	4,5			2,3	6b		2a,c 4a; 5a	
	CU	2			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f		1,2,3,6,7	4,5,8	1abc 2cd,ijk	3,5	7	1,2,6 3a	4,5			2,3		4a	2a,c 5a	
	SM	2			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f		1,2,3,6,7	4,5,8	1abc 2cd,ijk	3,5	7	1,2,6 3a	4,5		2,3			2a,c 4a		
L. KODIAK/SELIKOF	CU	1		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f		1,2,3,6,7	4,5,8	1abc 2cd,ijk	3,5	7	1,2,6 3a	4,5		2,3		6b	4a 5a	2a,c	
	SM	1			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f		1,2,3,6,7	4,5,8	1abc 2cd,ijk	3,5	7	1,2,6 3a	4,5		2,3			2a,c 4a		
M. GULF OF ALASKA	CL/ CU	2		1,2	3,4,5,6	1b 3a		1cd 3cd,4a,f			1,2,3,4 5,6,7,8	1abc 2cd,ijk	2a 3,5	7	1,2,6 3a	4,5		2,3		6b	2a,c 4a	5a	
	SM	2		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f		1,2,3,6,7	4,5,8	1abc 2cd,ijk	3,5	7	1,2,6 3a	4,5		2,3		6b	4a	2a,c 5a	
N. SOUTHEAST	CL	2		1	2,3,4,5,6	1b 3a		1cd 3cd,4a,f			1,2,3,4 5,6,7,8	1abc 2cd,ijk	2a 3,5	7	1,2,6 3a	4,5			2,3	6b	2c	2a 4a; 5a	
	CU	2		1,2	3,4,5,6	1b 3a		1cd 3cd,4a,f			1,2,3,4 5,6,7,8	1abc 2cd,ijk	2a 3,5	7	1,2,6 3a	4,5		2,3		6b	2a,c 4a	5a	
	SM	2			1,2,3,4,5,6	1b 3a		1cd 3cd,4a,f		1,2,3,6,7	4,5,8	1abc 2cd,ijk	2a 3,5	7	1,2,6 3a	4,5		2,3			2c 4a	2a	

P. NATURAL RESOURCE DEVELOPMENT COMPLEX

1. Introduction

A natural resource development complex is constructed to process timber into lumber or pulp, recover and concentrate hard rock minerals, or recover petroleum products. Timber processing and mineral recovery are labor-intensive industries which require service facilities for employees of the complex. These support facilities include housing, recreation, education, and community facilities and utilities for water supply, power, communication, and waste disposal. The recovery of petroleum products is a capital-intensive industry which requires a minimum number of employees and less support facilities. Each industry, however, requires a distribution and marketing network for raw, finished, or intermediate products. The transportation facilities can include a marine terminal, railroad, pipeline, or highway. In Alaska, all these methods can be expected to be utilized. At a minimum, service roadways and airports are needed to supply each development.

2. Resources Required to Complete Action

The development of a natural resource complex requires the resources identified earlier for clearing and grubbing, excavation, construction filling on land, drilling for water, foundation construction, road construction, community development, and recreational development, and may require dredging, construction filling in water and wetlands, or dam construction for power production. In addition, at least one of the categories of hard rock minerals, oil or gas, commercial logging, or agriculture must be available.

3. Permits and Regulations

Since the construction of a natural resource development complex is a composite of the engineering activities previously discussed, the agencies responsible for permits and plan approvals have been identified. Additional sources of air quality degradation and wastewater will require U.S. Environmental Protection Agency approval, as well as that of the Alaska Department of Environmental Conservation.

4. Description of Action and Equipment

The actions and equipment used are addressed in the earlier discussions of Section IV. The construction of an airport is a modification of roadway construction techniques. The size of the operation and the duration of the development phase could require a construction period of three to five years after project approval; maintenance and operation of the complex is long-term (greater than 15 to 20 years).

5. Impacts

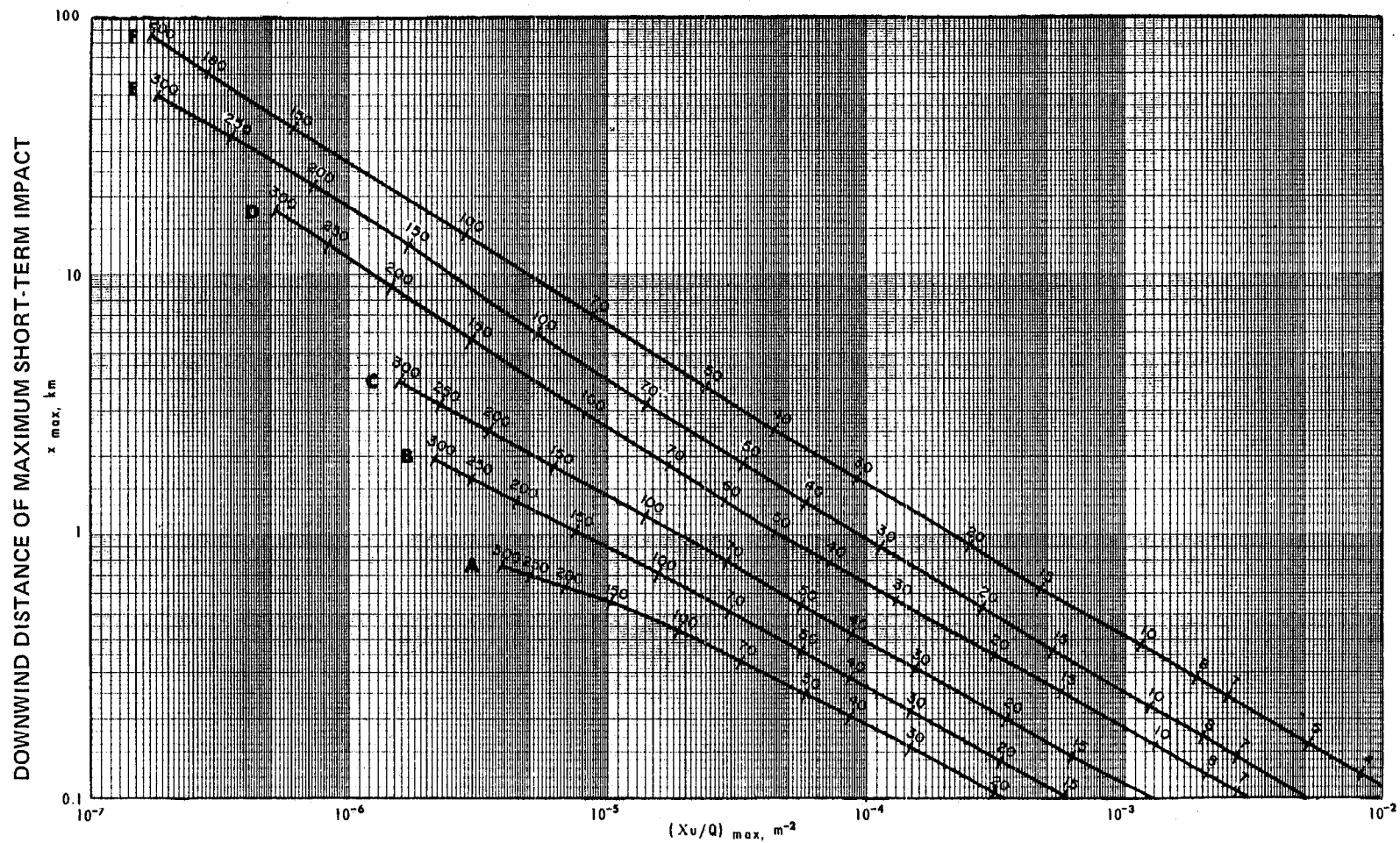
a. Air Quality

The air quality impacts due to natural resource development are distinguished from those of community and recreation development in that the amounts of pollutants released per unit area of development are higher, more power and heat are required, noxious and more harmful pollutants (besides those generally discussed above) are released, and the height of emission is higher in the atmosphere. The exhaust from a stack is often much hotter than the surrounding environment of air, so buoyancy forces propel it still further up into the atmosphere until the cooling of expansion and entrainment causes equilibrium to be reached. The wind acts on the exhaust plume, forcing its trajectory to become more and more horizontal. Dispersion is acting on the plume also, so that it spreads out in the vertical and horizontal as it gets further from the stack. Because the winds are stronger higher up in the atmosphere, the pollutants may be transported a significant distance downwind before they are removed from the atmosphere.

Stacks are often referred to as "point sources" because of the characteristic way that the concentrations are dispersed downwind. Several models are available for determining the "plume rise" or trajectory of the gases as they come from the stack and when they have been bent over by the wind and are moving horizontally. Other models take this information and calculate the dispersion of the gases and the concentrations that would be measured at ground level for various averaging times. For most industries, several stacks are involved so that the source is best described by several point sources. Figure 4-11 shows the relationship between atmospheric stability, effective height of emission, and the distance and concentrations to be expected for the maximum impact downwind for short-term averaging times.

New source performance standards set by the Environmental Protection Agency apply for several different types of sources, limiting the emission rates allowable for particulates and for some sources, sulfur dioxide, nitrogen oxides, sulfuric acid, hydrocarbons, and carbon monoxide. These sources include fossil-fuel-fired generators with greater than 250,000,000 Btu per hour of heat input (coal, residual oil, and natural gas burning plants), municipal incinerators, portland cement plants, nitric acid plants, sulfuric acid plants, asphalt concrete plants, fluid catalytic cracking units and storage in oil refineries, secondary lead smelters, secondary brass and bronze ingot plants, iron and steel plants, and sewage treatment plants. These industries must meet at least the new source emissions rates and may have to do even better to also satisfy national ambient air quality standards and significant deterioration limits.

The types of pollutants emitted depend on the industry. The amounts depend on the type of facility, size, types of processes employed, and extent of control



Source: Turner, 1969

Figure 4-11. Distance of Maximum Concentration and Maximum $\chi u/Q$ as a Function of Atmospheric Stability (curves) and Effective Height of Emission (numbers represent meters)

χ = Concentration in gm/m^3
 u = Wind speed in m/sec
 Q = Emission rate in gm/sec

achieved with pollution control devices. The development of a natural resource extraction complex is often intimately related to community development, since housing for workers, services, transportation, and maintenance and supply of the facility involve many more people than are actually employed on the industrial site. Construction of the facility involves clearing and grubbing and many of the other basic engineering actions. Fugitive dust, particulates, and gaseous emissions from the use of heavy-duty equipment, emissions from base camps, and pollutants from open burning are the most important aspects of the air quality impacts of construction. Community development impacts which are associated with industrial development are discussed in the section on community development (Section IV.N).

The emissions from industrial processes are closely related to the contents of the materials being processed; physical and chemical changes involved in processing the materials; fuel consumed in heaters, boilers, and incinerators; and transfer of the primary materials and products. Table IV-XXXVI shows an evaluation of the relative emissions of different pollutants by different industrial categories. The sizes and types of plants vary so much that each should be considered in detail prior to construction.

Besides the major pollutants emitted to the atmosphere, there are often significant amounts of hazardous pollutants emitted from industrial processes. These often result in not only vegetation damage and health problems for industrial workers, but contamination of river systems and locally grown food. Some of the effects of excesses of metals on plants are shown in Table IV-XXXVII. Asbestos mining and milling produce the greatest amounts of these pollutants. The manufacture of friction materials, asbestos cement products, and textiles, paper, and floor tile contributes 10 percent of total emissions. The use of asbestos in construction, insulation, fireproofing, and brake linings also results in emissions to the atmosphere (U.S. Environmental Protection Agency, 1973).

Mercury is particularly toxic; important sources include mercury processing; copper, zinc, and lead smelting; paint use and manufacture; use of mercury power cells containing electrolytic chlorine; combustion of coal in power plants; and some from incineration and other disposal (U.S. Environmental Protection Agency, 1973). Mercury has been used in the pulp and paper industry but, as use has declined, the importance of this source has declined. Agricultural uses of mercury include fungicides and bacteriocides for control of diseases of fruits, vegetables, and grains, and result in some emissions due to spraying (Davis, 1971d).

The primary sources of emissions of arsenic to the atmosphere include copper, zinc, and lead smelters. These emissions result from the processing of ore that contains arsenic. Agricultural uses of arsenic include the manufacture of pesticides including defoliants, herbicides, fungicides, and insecticides. Glass manufacture and coal combustion also result in arsenic emissions (Davis, 1971a).

TABLE IV-XXXVI. RELATIVE IMPORTANCE OF
DIFFERENT POLLUTANTS IN DIFFERENT INDUSTRIAL CATEGORIES

Industry	Pollutants				
	Particulates	SO _x	CO	HC	NO _x
Wood Processing Paper, pulp, plywood	A	A	C	B	A
Chemical Process Industry Nitric acid, sulfuric acid, printing, ammonia, etc.	A	C	B	A	B
Metallurgical Industry Primary and secondary smelters, iron and steel mills	B	A	B	C	B
Mineral Products Industry Asphalt, portland concrete, batching, phosphate rock processing, quarrying	A	B	C	C	B
Petroleum Industry Refining, storage	A	A	A	A	A
Food and Agriculture Feed and grain mills, fish processing, fertilizers	A	B	C	C	B

Key: A = Significant Source B = Important Source C = Not Significant

Source: U.S. Environmental Protection Agency, 1973

TABLE IV-XXXVII. PHYSIOLOGICAL AND MORPHOLOGICAL
CHANGES (MUTABILITY) IN PLANTS THAT MAY BE CAUSED
BY TOXIC QUANTITIES (EXCESSES) OF METALS

Element	Effect
Aluminum (Al)	Short and stubby roots; leaf scorch, mottling
Boron (B)	Dark foliage; marginal scorch of older leaves of high concentrations; shortened internodes; deformed; incomplete development; creeping forms; heavy (slow) pubescence; increased gall production
Chromium (Cr)	Yellow leaves with green veins
Cobalt (Co)	White dead patches on leaves
Copper (Cu)	Dead patches on lower leaves from tips; purple stems; chlorotic leaves with green veins; poorly developed (stunted) roots; creeping sterile forms in some species
Iron (Fe)	Incompletely developed (stunted) tops; thin or sometimes stubby roots; cell division disturbed in algae, resulting cells greatly enlarged
Manganese (Mn)	Chlorotic leaves; reddish coloration and lesions of stem and petiole; curling and dead areas on leaf margins; distortion of laminae
Molybdenum (Mo)	Incomplete development (stunting); yellow-orange coloration
Nickel (Ni)	White dead patches on leaves; chlorosis; apetalous sterile forms; abnormal forms
Zinc (Zn)	Chlorotic leaves with green veins; white dwarfed forms; dead areas on leaf tips; roots stunted or poorly developed
Uranium (U)	Abnormal number of chromosomes in nuclei; unusually shaped fruits; sterile apetalous forms; stalked-leaf rosette
Molybdenum, Copper (Mo, Cu)	Unusual development of black bands on the petals of <i>Eschscholtzia</i> sp. (black cross)
Lead, Zinc (Pb, Zn)	Development of different forms with the "double flower" in the <i>Eschscholtzia</i> sp.
Coal (bitumen)	Gigantism and deformity; abnormal repeated flowering

Source: Siegel, 1974

Vanadium compounds are major constituents in some crude oils, so important sources of vanadium emissions include the combustion of oil and coal (Davis, 1971e). Manganese sources include processing of manganese alloys, iron and steel manufacture, and coal combustion (Davis, 1971c). Beryllium emissions come primarily from coal and oil combustion and manufacture of alloys (Davis, 1971b).

The main sources of cadmium emissions to the environment include wind losses from tailing piles; smelting; use in electroplating, pigments and plastics; and from the combustion of fossil fuels. Cadmium is also emitted to the atmosphere due to the wear of rubber tires (Rossano and Lillis, 1974). The major sources of lead air pollution include gasoline combustion (93 percent), incineration of solid wastes, coal combustion, and secondary smelting (Rossano and McClannan, 1974).

Odors are often more noticeable as pollution than more harmful gases. Among the more noxious compounds are hydrogen sulfide ("rotten eggs") which is converted to sulfur dioxide, methyl mercaptans, dimethyl sulfide, dimethyl disulfide, and aldehydes. Pulp and paper industries and the combustion of diesel fuels are important sources of these noxious gases.

b. Noise

Noise from construction of a natural resource development complex would create a short-term impact similar in scope and magnitude to that discussed in the section on dam construction (Section IV.J). Long-term impacts would be associated with the noise levels created by the industrial complex itself, transportation of labor and materials, and community activities. The major sources of noise from industrial processing facilities can generally be divided into two major categories by usage: (1) continuous sources and (2) intermittent sources. Table IV-XXXVIII shows some of the basic types of equipment within these two categories, together with the primary mode of use.

In order to assure that all health and safety requirements are met by the operation of the industry, all bid specifications to supply vendors should require submission of octave band sound pressure levels for all operating equipment, to be measured at 3 feet under full-capacity operations. The express purpose of such specifications is to ensure compliance with the provisions of the Occupational Safety and Health Act (OSHA). Of equal benefit is the ability of the design engineers to form a simulated composite of the total equipment noise levels which can be expected during plant operation. The composite can then be used to determine if any significant noise problems would be created within the plant or surrounding community and appropriate remedial action could be taken to eliminate the problems. In any case, siting of industrial facilities should be done so that no perceptible interference occurs at the nearest noise-sensitive property (houses, hospitals, schools, etc.). For adjacent industrial property, an acceptable noise level may be 65 to 70

TABLE IV-XXXVIII. TYPICAL INDUSTRIAL NOISE SOURCES

Category/Usage	Equipment Type		Uses
Continuous Sources	Reciprocating Machinery	— Reciprocating Compressors	Operations
	Rotating Machinery	— Centrifugal Compressors Air Blowers Electrical Motors Tower Fans	Operations
	Control Valves	— Various Systems	Operations
	Air Blowers	— Fin-Fan Coolers	Operations
	Fired Burners	— Process Heaters Boilers	Operations
Intermittent Sources	Flare System	— Relief Valve	Emergency
	Relief Valves	— Steam System	Emergency and Periodic Testing
	Signals	— Fire/Plant Whistle	Emergency
	Pneumatic Tools	—	Maintenance

Source: Robert Brown Associates/John Graham Company, 1974

dBA; for adjacent commercial or residential property, the required noise level at the property line may be 55 to 60 dBA.

Transportation noise must also be considered in the siting and development of large industrial facilities. Expected volumes for auto and truck traffic, rail transport, and aircraft use should be assessed and the impact of each source on the community should be modeled to determine if the resulting levels will create significant impacts. A guide to determining the impact of transportation noise on the community is contained in the general discussion of noise impact, Section II.B.

c. Water Resources

The construction of a natural resource development complex is a composite of the engineering activities previously discussed. The development can be expected to cause similar effects identified for each engineering activity over a period of 3 to 4 years. Following construction of the complex, water quality degradation can be expected to continue from sewage effluents, stormwater runoff, leachates from spoil disposal sites and waste materials, sanitary landfills, etc., for a period greater than 15 to 20 years.

The Clean Water Act, officially known as the Federal Water Pollution Control Act of 1972 (PL 92-500), established a national permit program, defined in Section 402 of the Act as the National Pollutant Discharge Elimination System (NPDES). It is now mandatory that a National Pollutant Discharge Elimination System permit be obtained to discharge any type of pollutant into the nation's waters. The permit regulates what may be discharged by a facility as well as how much. Specific limits on the effluent from each source have been established. New facilities (new sources) are hence committed to comply with all applicable provisions of the law. The State of Alaska does not yet have the authority (June 23, 1975) to issue these permits; however, permits are issued through Region X of the Environmental Protection Agency.

d. Terrestrial Biology

Construction of a natural resource development complex is a composite of many of the engineering actions previously described. However, since many of these actions occur simultaneously and over long periods of time, the total impacts on the terrestrial communities would be more severe than the "sum" of the individual actions. Impacts on terrestrial vegetation and wildlife will be unique for the specific resource complex anticipated. For example, air pollution first appeared as a problem in southeast Alaska with development of gold mining on Douglas Island. Sulfide and chloride fumes produced in the gold recovery process killed trees on several hundred acres (Laurent, 1974). It was only after the closure of the last mine in 1924 that the air pollution was eliminated and affected areas have been restocked with forest vegetation.

Proposed iron ore processing plants at Klukwan, Port Snettisham, Union Bay, and on the Kasaan Peninsula could cause similar air pollution problems. However, equipment now available can hold emissions to nontoxic levels and therefore detrimental impacts may be avoided. Pulp mills may also cause air pollution problems. With the completion of the Ketchikan pulp mill in 1954 and the Sitka pulp mill in 1959, sulfur dioxide emissions from the mills have injured and killed Sitka spruce, western hemlock, western red cedar and Alaska cedar. The effluents from the Sitka pulp mill have destroyed approximately 400 acres of trees (Laurent, 1974). In general, sulfur dioxide from pulp mills, fluorides from aluminum and phosphate plants, and hydrocarbons from the production and refining of petroleum products and evaporation of solvents are especially damaging to the native vegetation. Their distinctive effects on plants are described in Section II.D.3. Animals are also influenced by the pollutants; however, most are mobile and may emigrate from the locality if they can find an area which is suitable and unoccupied.

Communities are usually built within the vicinity of a resource development complex. This means that man/animal interactions (intentional, such as hunting, and unintentional, such as vehicular accidents) will increase and animals will have to behaviorally adjust or emigrate from the region. However, wildlife species that adjust are frequently considered pests and are hunted or destroyed.

e. Aquatic Biology

Since natural resource development incorporates the engineering actions described previously, the impacts on aquatic life have been described with regard to the separate activities. The greatest impacts are expected to occur from increases in human activity and are reflected in the discussion of community development impacts in Section IV.N. Impacts to the natural environment will vary with the type of resource developed. Impacts from this engineering action would be the same as for cumulative smaller actions (discussed in Sections II.E.1 through II.E.7), but would result in chronic detrimental changes to aquatic life. Effects of pollutants from resource extracting activities (e.g., acid mine drainage, siltation) and in combination with pollutants generated by the associated required housing and road construction (e.g., stormwater runoff, sewerage) result in cumulative impacts greater than actions considered separately or simply added. In other words, as combinations of actions increase arithmetically, the deleterious impacts increase geometrically. Since deleterious effects of water pollutants are generally synergistic, impacts of a resource extraction complex generating several potential pollutants can be very severe.

f. Soils

Impacts from both Level I and Level II engineering actions are expected to occur with this type of development; however, the cumulative effect of the impacts identified may be greater than their effects separately. In general, site-specific soils studies

are conducted prior to initiation of any major development activity. Such studies take into account the major characteristics of the surface and subsurface soils and geology, the load bearing strength, the depth to groundwater, and the seismic character of the site and area. These findings are then used in the facility's design and the foundation is constructed according to detailed specifications. Depending on these site-specific findings, the impacts will vary due to the use of various construction requirements.

g. Interactions

Those impacts described under exploration for oil and gas (Section IV.H) and exploration and recovery of hard rock minerals (Section IV.K) are applicable to the natural resource development complex. Impacts identified for community development (Section IV.N) are also applicable, but are less severe. Initial development in remote areas will result in increased wildlife/human encounters. Again, the cumulative effects of industrial development are expected to have a far broader effect on the environment due to greater space requirements, increased human population, and greater amounts of pollutants generated.

IMPACT ANALYSIS, NATURAL RESOURCE DEVELOPMENT COMPLEX

REGIONS	PHYSIOGRAPHIC UNITS	POTENTIAL	AIR QUALITY			NOISE EXPOSURE			WATER RESOURCES			TERRESTRIAL BIOLOGY			AQUATIC BIOLOGY			SOIL RESOURCES			INTERACTIONS		
			SECTION II, PAGES 2-1 TO 2-20 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-20 TO 2-36 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-36 TO 2-45 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-46 TO 2-60 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-60 TO 2-66 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-66 TO 2-70 REFERENCED PARAGRAPHS			SECTION II, PAGES 2-71 TO 2-76 REFERENCED PARAGRAPHS		
			SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW	SEVERE	MODERATE	LOW
A. ARCTIC	CL	2		3,4,5,6	1,2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b 2c,d,e,i,j,k	1c 5,6	3,4	1,2,3,4 5,6,7			2,3,5,7,9	8		2a;3 4a;5b		
	CU	2	3,4,5,6		1,2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b 2c,d,e,i,j,k	1c 5,6	3,4	2,3,4,5,6,7	1		2,3,5,7,9	8		2a;3 4a;5b		
	SM	0																					
B. NORTHWEST	CL	2		3,4,5,6	1,2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b 2c,d,e,i,j,k	1c 5,6	3,4	1,2,3,4 5,6,7			2,3,5,7,9	8		2a;3 4a	6b	
	CU	2		3,4,5,6	1,2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b 2c,d,e,i,j,k	1c 5,6	3,4	1,2,3,4 5,6,7			2,3,4,5,6 7,9	8		2a;3 4a	6b	
	IL	0																					
	IU	1		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b 2c,d,e,i,j,k	1c 5,6	3,4	1,2,3,4 5,6,7			2,3,4,5 7,9	8		2a;3 4a		
	SM	0																					
C. UPPER YUKON/ PORCUPINE	IL	2	1,3,4,5,6		2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b 2c,d,e,i,j,k	1c 5,6	3,4	2,3,4,5,6,7	1		5,7	2,3,8,9		2a 3	4a	
	IU	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6,7	1		2,3,4,7	5,8	9	2a;3 4a;5b		
	SM	1			1,2,3,4,5,6	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6,7	1		4	2,3,5,7,8,9		2a 3	4a	
D. TANANA	IL	2	1;2a;c;d 3,4,5,6	2b		1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b;c	2c,d,e,i,j,k 5,6	3,4	2,3,4,5,6		1,7		8	2,3,5,7	2a 3		4a
	IU	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6	1	7		2,3,4,7,8		2a 3	4a	
	SM	1			1,2,3,4,5,6	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	1,2,3,4,5,6	7			2,3,4,5,7,8		2a 3	4a	
E. YUKON/KOYUKUK	IL	1	1,3,4,5,6		2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b;c	2c,d,e,i,j,k 5,6	3,4	2,3,4,5,6,7	1			2,3,4,7,8	9	2a 3	4a	
	IU	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	1,2,3,4,5,6	7		2,3	4,7,8	9	2a;3 4a		
	SM	1			1,2,3,4,5,6	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6,7	1		9	2,3,7,8		2a 3	4a	
F. YUKON/ KUSKOKWIM DELTA	CL	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b;c	2c,d,e,i,j,k 5,6	3,4	1,2,3,4 5,6,7			5,7,9	2,3,8		2a;3 6b	4a	
	CU	1			1,2,3,4,5,6	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	1,2,3,4 5,6,7			2,3,4,5,7			2a 3	4a	
	SM	1			1,2,3,4,5,6	1b 3a,b,d,e	1c 3c	1d 3f		1,2,3,4 5,6,7	8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6	7		2,3,4,5,7			2a 3	4a	
G. UPPER KUSKOKWIM	IL	2	1,3,4,5,6		2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a,b;c	2c,d,e,i,j,k 5,6	3,4	1,2,3,4 5,6,7				5,8,9	2,3,7	2a 3	4a	
	IU	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	1,2,3,4 5,6,7				2,3,4,5,8,9		2a 3	4a	
	SM	0																					
H. COOK INLET	CL	2	1;2a;c 3,4,5,6	2b,d		1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6	1	7		8	2,3,5,9	3	2a	4a
	CU	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6	1	7		2,3,4,8	9	3 4a	2a	4a
	IL	0																					
	IU	0																					
	SM	2		3,4,5,6	1,2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6	7	1	4	2,3,8,9		2a 3	4a	
I. COPPER RIVER	IL	2	1,3,4,5,6		2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6		1,7	5,7	2,3,8,9		3	2a 4a	
	IU	0																					
	SM	2			1,2,3,4,5,6	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6	7	1		2,3,4,8		2a 3	4a	
J. ALEUTIAN	CL	2		1,2,3,4,5,6		1b 3a,b,d,e	1c 3c	1d 3f		1,2,3,4 5,6,7	8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6		1,7		8	2,3,5,9	3	2a 4a	
	CU	2		1,2,3,4,5,6		1b 3a,b,d,e	1c 3c	1d 3f		1,2,3,4 5,6,7	8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6		1,7		2,3,4,8,9		3 6b	2a 4a	
	SM	2		1,2,3,4,5,6		1b 3a,b,d,e	1c 3c	1d 3f		1,2,3,4 5,6,7	8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6,7		1	4	2,3,8	9	3	2a 4a	
K. BRISTOL BAY	CL	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	1,2,3,4 5,6,7			8	2,3,5,9	2a 3	4a		
	CU	2		1,2,3,4,5,6		1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	1,2,3,4 5,6,7			4	2,3,8	9	2a 3		4a
	SM	0																					
L. KODIAK/SHELIKOF	CU	2		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6,7		1	4	2,3,8	9	3 6b	2a 4a	
	SM	1			1,2,3,4,5,6	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6,7		1	4	2,3,8	9	3	2a 4a	
M. GULF OF ALASKA	CU/	2		1,2,3,4,5,6		1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c;2g 3,4	2,3,4,5,6		1,7		4	2,3,8	9	3	2a 4a
	SM	2	3,4,5,6	1	2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c 3,4	2,3,4,5,6,7	1		4	2,3,8	9	3 6b	2a 4a	
N. SOUTHEAST	CL	1		1,3,4,5,6	2	1b 3a,b,d,e	1c 3c	1d 3f		1,2,3,4 5,6,7,9		1a	1b;5;6 2c,d,e,i,j,k	1c;2g 3,4	2,3,4,5,6,7	1		8	2,3,5,9	3 6b	2a	4a	
	CU	2		1,2,3,4,5,6		1b 3a,b,d,e	1c 3c	1d 3f		1,2,3,4 5,6,7,9		1a	1b;5;6 2c,d,e,i,j,k	1c;2g 3,4	1,2,3,4,5,6	7		4	2,3,8	9	3 6b	2a 4a	
	SM	2		3,4,5,6	1,2	1b 3a,b,d,e	1c 3c	1d 3f	1,2,3,4 5,6,7		8	1a	1b;5;6 2c,d,e,i,j,k	1c;2g 3,4	2,3,4,5,6		1,7	4	2,3,8	9	3 6b	2a 4a	

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