A PROGRAM for COOK INLET ALASKA

for the Collection, Storage and Analysis of Baseline Environmental Data

Institute of
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A PROGRAM FOR THE COLLECTION, STORAGE, AND ANALYSIS OF BASELINE ENVIRONMENTAL DATA FOR COOK INLET, ALASKA

By David G. Wagner, R. Sage Murphy

and Charles E. Behlke

A program for the collection, storage adn analysis of baseline environmental data for Cook Inlet, Alaska

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I. INTRODUCTION

BACKGROUND

The State of Alaska is unique in the sense that, although it is undergoing an unbelievably rapid development, many of its rivers, lakes, and estuaries are in their natural unpolluted state. The technology of water pollution control and water quality management has now advanced to the point that natural resource development and industrial and municipal expansion are possible without the attendent pollution of the environment.

Cook Inlet is the fastest growing area in industrial development in the State of Alaska. Increases in pressures of population and industrialization make it imperative that the water resources of Cook Inlet be studied and managed in the most efficient manner possible. In order to effect the most efficient water resource management, data and information describing the existing state of the Inlet waters must be developed.

The Alaska Water Laboratory, Federal Water Pollution Control Administration, Department of the Interior contracted the Institute of Water Resources at the University of Alaska to develop a plan for describing the existing environmental conditions within the Cook Inlet estuary. This plan is entitled "A Program for the Collection, Storage, and Analysis of Baseline Environmental Data for Cook Inlet, Alaska," and is funded by the Federal Water Pollution Control Administration (Contract No. 14-12-449).

SCOPE AND OBJECTIVES

The scope of this report is to provide a general, yet comprehensive, description of the Cook Inlet System which will serve as a basis for understanding the interrelated natural and man-made factors governing its future; to present a program of field research studies for the estuarine environment that will describe the existing state of the Inlet with respect to the water quality and biota; to provide a framework whereby the program of studies can be evaluated and redirected in light of the preliminary results; and, to provide a method of storing and analyzing the data from the investigations so that it can be made available to interested parties in the most efficient manner possible.

The objectives of this report are to:

Describe the existing environmental conditions of Cook Inlet in the areas of hydrology, hydraulics, biology, physical and chemical characteristics of the water, and the sediment characteristics, and to determine seasonal variations of the above factors.

Develop an up-to-date waste discharge inventory to describe the quantity and type of municipal, industrial, and agricultural waste inputs to the Inlet.

Develop information on optimum locations of waste effluent discharge to Cook Inlet.

Investigate special problems which are now occurring in Cook Inlet due to oil spills and existing and proposed waste discharges.

Develop a framework for directing and evaluating estuarine data collection programs.

Develop a data storage facility for cataloging, storing, analyzing and publishing data collected from estuarine data collection programs.

ORGANIZATION

The development of the program for water quality studies described herein, was accomplished by Institute of Water Resources personnel working in close collaboration with governmental agencies and industry of the State of Alaska.

The project was funded by the Alaska Water Laboratory of FWPCA under the direction of Mr. E.K. Day. Mr. Carl Nadler and Mr. Merritt Mitchell of the Alaska Water Laboratory acted as Project Officers for this contract (No. 14-12-449).

Dr. George Tchobanoglous of Stanford University served as a general consultant.

Dr. Donald Hood of the Institute of Marine Science at the University of Alaska served as a consultant on oceanographic studies. His research staff provided information on oceanographic investigations.

Mr. David Clack of the Santa Clara County Flood Control and Water District served as a consultant on data management and analysis systems.

ACKNOWLEDGMENTS

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The following persons gave heartily of their time and effort in supplying information to the project.

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II. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

I. Study Area

1. Cook Inlet is largely undeveloped and does not have major pollution problems at the present time.

2. Increasing industrialization through resource exploitation is expected to cause localized pollution in the very near future. Sewage discharge from Anchorage, industrial waste discharge from the petrochemical industry near Kenai, and oil spills from pipeline breaks and platforms are causing minor problems at present. These are expected to have a much greater influence in the future.

3. The major industries now present in the Inlet are commercial fishing, petroleum production, and petrochemical industries. Multiple use of the water resources of Cook Inlet requires that more knowledge about the environmental conditions of the Inlet be developed.

4. There is very little information available describing the ecology or physical conditions of the Inlet which would allow judicious management of the water resources of Cook Inlet.

III. Data Collection Program

1. Based on a review of existing data acquired during this report contract, data collection programs need to be initiated to collect hydrographic and hydrologic, geologic, physical and chemical, and biological data to adequately describe the existing conditions of the Inlet.

2. There are localized areas where small scale investigations may be initiated ($50,000 to $100,000 funding level). These special studies have been described within this report.

3. Optimum locations for waste discharge outfalls cannot be selected with existing available information but can be determined based on results from the proposed hydrographic and hydrologic data collection program.

4. Based on review of other major estuary investigations in the United States, a large scale Inlet-wide baseline characterization is more productive than a series of segmented smaller scale investigations. This is true in both economy and valid information acquired.

III. Data Storage Facility

1. To provide for an orderly method of storage, analysis, and retrieval of baseline data for the massive amounts of data acquired from the estuary investigations, a computer facility is required.

2. The University of Alaska, with the largest scientific computer facility in the State of Alaska, is the ideal location to establish a data bank.

3. The data bank should be developed and operated by a group of professional personnel experienced in data bank development.

4. Proper specifications, job manuals, and documentation of the program are of paramount importance and should be included in the development of the data bank.

5. The data storage and analysis facility described in this report can, with very little modification, be expanded to act as a water resources data bank for the State of Alaska. The need for this data bank has been expressed by the Inter-Agency Technical Committee for Alaska.

IV. Program Implementation

1. The proposed program presented in this report is a basic and general "blueprint" for a plan to characterize Cook Inlet. Optimum sampling stations and cruise times have been shown.

2. In order to carry out a baseline investigation of the magnitude proposed in this report, a group of professional personnel should be committed full time to specifically manage and coordinate the various investigations.

3. A computer simulation model is an valuable tool in predicting and evaluating data derived from field investigations. The model should simulate both the hydraulics (tides and currents) and the water quality (chemical constituents) of the Inlet.

4. Past experience indicates that it is more efficient and economical to execute an Inlet-wide master characterization study shown by the optimum program plan in Chapter VI.

5. An alternative schedule of investigations is presented in which a series of investigations as described and priorities are established. This priority of investigations if followed will yield data that can be used to characterize the physical, chemical and ecological conditions of Cook Inlet. These smaller scale studies are more limited in the results obtained for the amount of funds expended.

RECOMMENDATIONS

The recommendations are:

1. A program management staff be formed to develop specific objectives and job specifications for a baseline investigation of Cook Inlet.

2. A data storage and analysis computer facility and a computer simulation model be developed as aids to the management staff in managing and coordinating the proposed program.

3. A four phase, coordinated study should be initiated while pollution problems are not major in the Cook Inlet estuary. Ideally, one year should be devoted to program planning and three years should be devoted to field investigations, as proposed in this report.

4. The optimum program should be funded as a whole and for the entire length of the proposed program. Small localized investigations may be funded separately, but, as these are completed, emphasis should be given to accomplishing an Inlet-wide characterization. Ideally, segmented environmental characterization studies should not be attempted. However the proposed study plan has been designed to allow funding in small segments.

5. A water quality surveillance station grid should be developed after more complete information is accumulated on the tide and current characteristics of the Inlet.

6. The Anchorage Area special pollution study should be initiated at least two years before the primary sewage treatment plant is operational.

III. THE COOK INLET ESTUARY SYSTEM

An estuary and its environs form one of the most complex ecological systems known to man. This, coupled with the fact that most estuaries are highly developed industrially and commercially, makes their characterization extremely difficult. The purpose of this chapter, therefore, is to provide a general, yet comprehensive, description of the Cook Inlet area which will serve as a basis for understanding the interrelated natural and man-made factors governing its future. The description is presented in terms of 1) the physical characteristics of the study area, 2) the indigenous biota, 3) the natural resources and industrial development, and 4) the existing water quality. In addition, pertinent engineering reports dealing with the area have been summarized and reviewed as they relate to this study. Additional details on the Cook Inlet estuary system are presented in Chapter IV in connection with the proposed sampling program and studies.

THE STUDY AREA

Cook Inlet forms a shaft of water penetrating deep into the mountains of south central Alaska. The Inlet is a tidal estuary of the Gulf of Alaska and is surrounded by glacier-covered mountains on three sides as well as more than 100 square miles of tidal marsh. The Inlet and its two extensions at the head end, Turnagain and Knik Arms, comprise the Cook Inlet Estuary system which is the subject of this report.

Location

The estuary lies between latitudes 59° and 61° 30' north and longitude 149° and 154° west (Figure III-1). The Inlet itself is more than 150 n. miles long and 50 n. miles wide at the mouth (Figure No. III-2). The Inlet divides at the head into two arms, Turnagain Arm and Knik Arm, being 43 n. miles and 45 n. miles long, respectively. [163]

Bordering Cook Inlet on the east are the Kenai Peninsula and the Kenai Mountains. To the northeast at the head of the Inlet lies Anchorage, the largest city in Alaska, at the base of the Chugach Mountains, and situated at the junction of the two arms of Cook Inlet (Figure No. III-2). To the west and southwest the Aleutian Range borders Cook Inlet and extends down the Alaska Peninsula to form the Aleutian Islands.

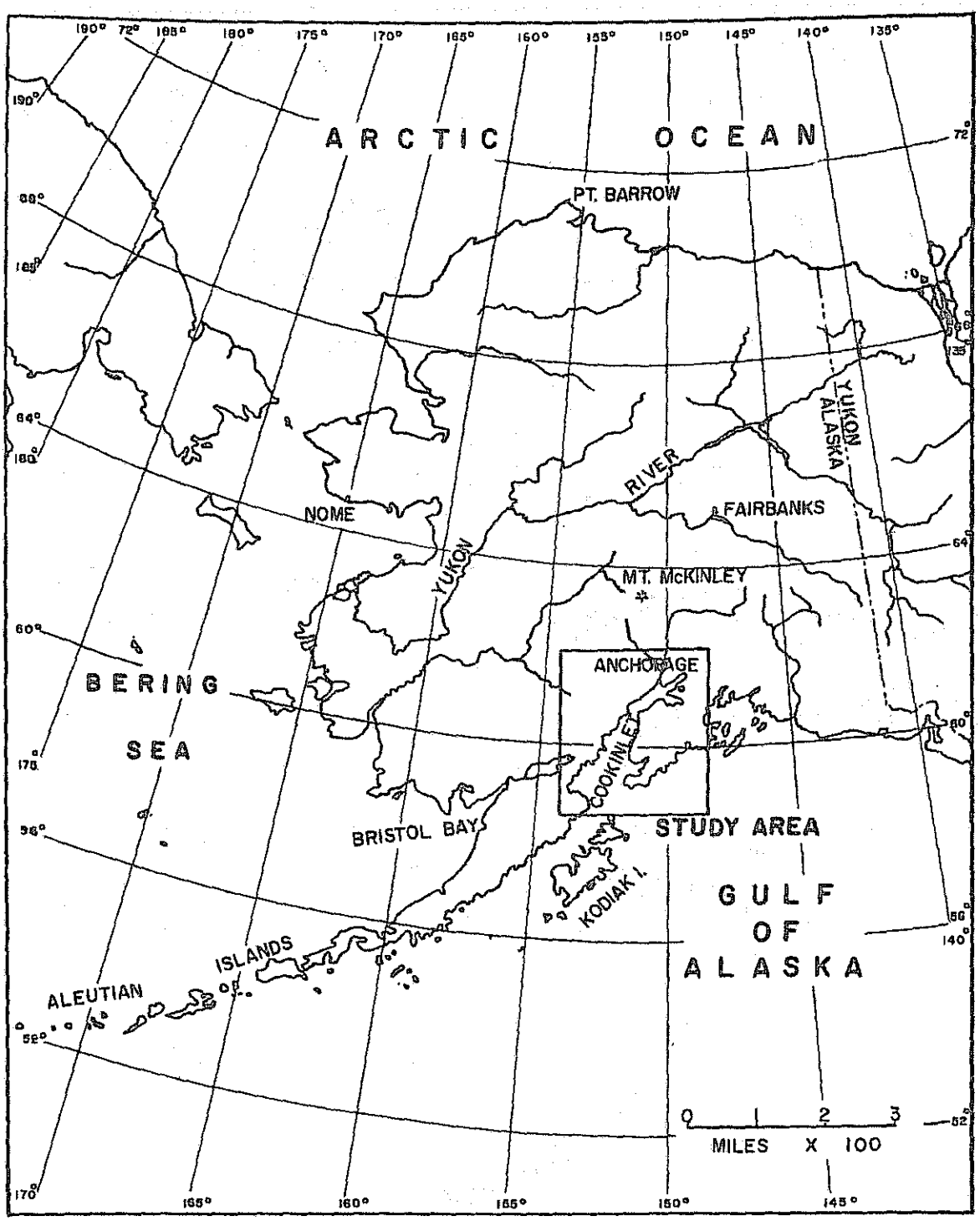
Structure

The estuary can be divided into two natural regions, a northern portion and a southern portion, by a natural topographic feature, the West and East Forelands. The bottom of the Inlet is extremely rugged, containing many shoals and deep areas. The average depth at the mouth is 300 feet. The area between Cape Elizabeth and Cape Douglas at the Inlet mouth is similar to an oceanic environment. The depth of the area near the forelands averages 120 feet and at the head averages 60 feet. Knik Arm averages 50 feet for one-half of its length and rapidly shallows to a mud bank. Turnagain Arm shallows within the first 10 n. miles to a large mud flat cut by many tidal channels (Figure No. III-3). [163]

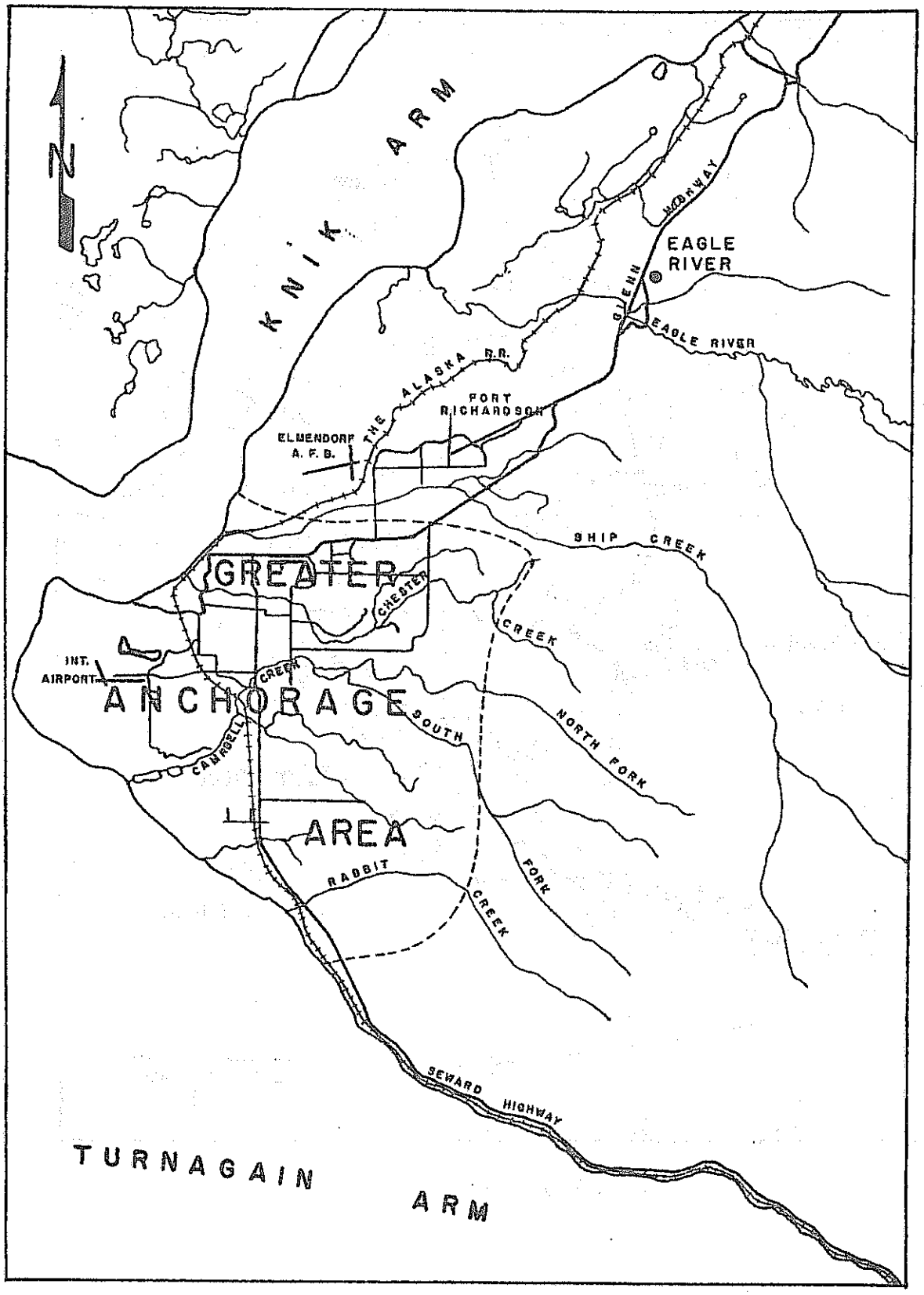
Geography

Surrounded on three sides by mountains with glaciers emanating from ice-fields atop the Alaska Range, the Aleutian Range, the Chugach Mountains, and the Kenai Mountains, the Inlet waters provide an important base for commercial fishing, hunting, recreation, transportation, and petroleum production.

FIGURE III-1

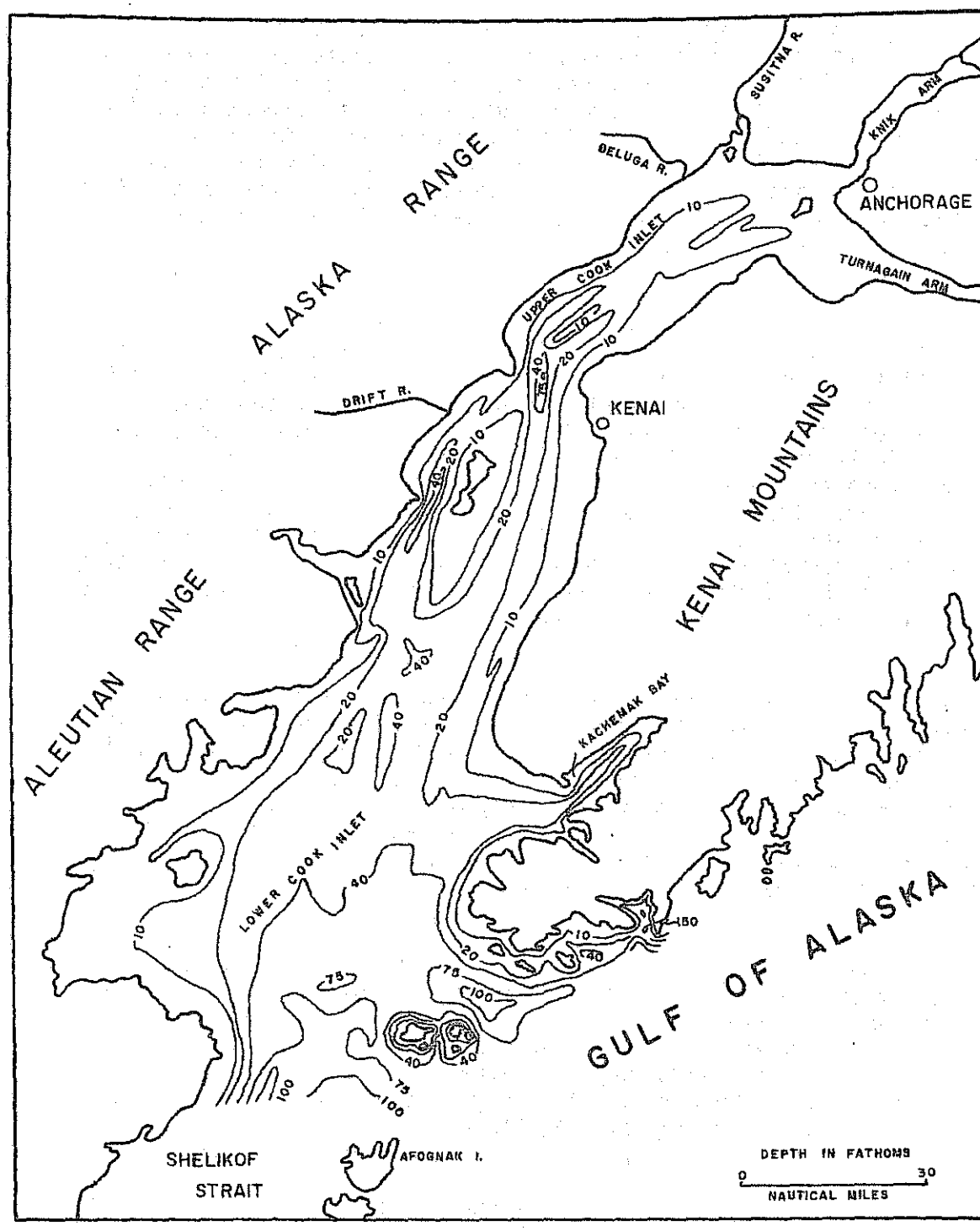


LOCATION MAP



ANCHORAGE AREA

FIGURE III-3



COOK INLET

West and Northwest Sides. The Susitna River and the Susitna Lowland, a flat marshland of lakes and bogs, lie directly north of the head of Cook Inlet and provide a habitat for the propagation of waterfowl and wildlife. The west shore of Cook Inlet lies directly at the feet of the isolated mountains of the Aleutian Range. Since the only access to the west side of Cook Inlet is by boat or airplane, this mountain range contains vast wilderness areas, some of which are virtually untouched by humans. This area provides some of the best fishing and hunting in the State of Alaska.

The waters of Knik Arm flow into the head of Cook Inlet. Flowing southwest, Knik Arm is fed by the Knik and Mantanuska Rivers, both glacial streams, the latter originating in the Talkeetna Mountains. In the 1930's, the depression and drought conditions in the lower United States forced many farmers from their homes; some of them came north to Alaska to settle in the newly opened Matanuska Valley. The fertile ground and long summer days make for the "giant" vegetables known throughout the United States. The Palmer Experiment Station, located at Palmer on the Matanuska River, is responsible for studying and proposing new methods of increasing the agricultural yield of Alaska. In time, it is hoped that the State will become self-sufficient in growing and utilizing its agricultural products.

The Knik River, which joins the Matanuska River to form Knik Arm receives most of its flow from Lake George, a moderately sized lake high in the Chugach Mountains which is annually blocked by Knik Glacier. As the lake level rises, the glacial blocking is overtopped. With the resultant melting and channeling of the glacier by the lake waters, an extremely large flow of water is dumped into the Knik River channel, moving large amounts of sediment, and causing the salinity of the water in Knik Arm and upper Cook Inlet to decrease rapidly.

Northeast side - Anchorage Area. Bounded by Knik Arm on the north and west, Turnagain Arm on the southwest, and the Chugach Mountains on the east, lies Anchorage, the largest city in Alaska, with a total metropolitan population of over 112,000. Anchorage lies on a triangular plateau of approximately 100 square miles which slopes up to the front of the Chugach Mountains. The City is the center of transportation, commerce, and industry for the State.

The Anchorage International Airport is the major stop for polar flights to Europe and trans-Pacific flights to Japan and the Orient. It also serves as the base for the major Alaskan airlines and the bush routes which supply a majority of the towns and villages of the State with staples and necessities of living. With few highways and roads, even items such as machinery and vehicles are transported by plane. Merrill Field, a downtown airport is the home base for many private planes,

including service planes for the oil industry in Cook Inlet. Lake Hood and Lake Spenard host the world's largest concentration of float planes.

As early as 1904 President Theodore Roosevelt urged construction of a railroad from the Gulf of Alaska to the Yukon River as a necessity for opening up the Alaskan coal fields. During 1914 surveys were made examining possible routes for the railroads; construction started in 1915. Over 2,000 persons converged at the mouth of Ship Creek on Cook Inlet to establish a construction camp and the headquarters for the railroad. The Ship Creek site provided rich natural resources, a farming area, access to a deep sea waterway, and closeness to the Matanuska coal fields. The Ship Creek landing was renamed Anchorage and, in 1916, had a population of 6,000 persons. The railroad was completed to Seward in 1918 and to Fairbanks in 1921.

When Fort Richardson was constructed in 1940, military strategy demanded a highway connecting the military bases with the States. In 1942 the famous Alcan Highway was under construction; in 1951, a highway from Anchorage to Seward was completed. After a new army installation was constructed in 1950 also named Fort Richardson, the old installation was renamed Elmendorf Air Force Base.

Today, a majority of Alaska's population lives within close proximity to Anchorage. With the city as the transportation hub of a supply network for this population, Anchorage has developed into a business, wholesale, and distribution center for the State (Table No. III-1).

Anchorage is a major seaport gaining impetus when the seaports of Seward and Whittier were destroyed during the 1964 earthquake. Since supplies for reconstruction were desperately needed, the Port of Anchorage developed into the modern, year-round facility that today is handling over one million short tons of cargo per year. [184] The petroleum industry, which has contributed greatly to the stimulation of commerce and progress in the entire Cook Inlet area, will be treated as a separate subject later in this report.

Southeast of Anchorage on the Seward Highway, overlooking Turnagain Arm is the ski resort of Alyeska, a rapidly developing resort area offering excellent recreational facilities. Skiers from all nations of the world come to Alyeska to practice on the excellent slopes.

East Side. The Kenai Peninsula is connected to the mainland of Alaska by a neck of land located at the head of Turnagain Arm. Portage, on the Turnagain Arm side of the neck, and Whittier on Prince William Sound, are connected by an Alaska Railroad tunnel. The Seward highway enters the Kenai Peninsula near Portage.

TABLE III-1
SELECTED ECONOMIC DATA
(Anchorage, Alaska)

	1959	1960	1961	1962	1963	1964
Postal Receipts	$ 1,252,217	$ 1,432,785	$ 1,518,765	$ 1,576,700	$ 1,846,800	$ 2,117,421
Telephones in Service	18,200	21,523	23,214	23,253	25,348	27,098
Lighting and Power Customers	20,026	21,989	22,733	22,518	23,880	25,356
Municipal Water Customers (1)	6,660	7,511	8,827	9,609	9,926	9,836
Kilowatt Hours Sales Total	147,723,380	167,918,144	188,107,143	218,365,464	245,241,641	276,885,936
Building Permits Number (1)	956	1,013	895	1,095	1,282	1,806
Building Permits Value (1)	15,745,711	23,374,623	13,087,994	18,087,731	18,079,589	28,790,565
Vehicle Registration	36,577	41,383	44,208	46,468	47,810	55,102
Assessed Value Real Property (1)	139,935,524	183,980,509	218,590,764	243,027,416	263,272,850	303,913,358
Assessed Value Personal Property	51,418,213	56,012,824	55,187,092	56,528,250	64,050,780	82,604,000
Total Assessed Value	191,353,737	241,993,333	273,777,856	299,555,666	327,323,630	386,517,358
Property Taxes Collected	2,139,470	2,590,089	3,302,281	3,657,022	3,461,437	5,249,799
Total Bank Assets	102,953,290	139,696,379	146,315,003	201,215,980	209,599,432	214,834,093
Bank Deposits	97,066,771	130,234,818	133,625,006	183,337,609	191,401,500	186,348,452
Bank Loans and Discounts	51,141,727	64,305,909	73,320,259	102,342,636	105,522,417	90,367,715
School Enrollment	10,189	11,208	12,624	14,004	15,913	16,225

(1) City of Anchorage only

From Tryck, Nyman & Hayes [184]

The Kenai Mountains extend for over 150 miles from Portage to Cape Elizabeth at the end of the Kenai Peninsula. Many of the mountains in the central section of the Kenai Range are covered by the Harding Icefield which, during the Pleistocene Period, generated glaciers covering a large area of the Cook Inlet Lowland. The Kenai Mountains are vast and, for the most part, uninhabited -- especially in the lower reaches of the range.

Lying at the foot of the Kenai Range between the Range and Cook Inlet is the Kenai Lowland. One hundred miles long and an average of 35 miles wide, the Lowland area contains oil and gas fields, recreational areas, lakes and swamps abounding in wildlife (the Kenai National Moose Range), small villages dependent on commercial fishing, and rapidly expanding towns such as Kenai.

The only highway link to Anchorage and Seward, the Seward Highway, meets the Sterling Highway deep in the Kenai Mountains. The Sterling Highway divides at Soldatna to form two branches, one to Homer, the other to the industrial areas of Kenai and Nikiski.

Oil was first discovered in the Swanson River area in 1957 and production began a few years later. By 1966, oil production from this field totaled over 50,000,000 barrels. There are 58 oil wells in this field as well as 11 gas wells which supply Anchorage with natural gas. In 1963, oil was discovered near Middle Ground Shoal in the center of Cook Inlet, and by December 1965 production was exceeding 1,000 barrels of oil per day per well. [184] The discovery of oil has contributed to the rapid growth of the communities of Kenai and Nikiski. Kenai had been dependent upon commercial fishing and was the location of several canneries. Now, a urea and ammonia-producing plant, a natural gas liquification plant, and several refineries have been constructed along the shore of Cook Inlet near Kenai and the area is fast becoming a center of industrialization.

Southeast, along the east shore of Cook Inlet, the communities of Kasilof, Ninilchik, Anchor Point, Homer, and Seldovia are important commercial fishing villages. Their economies are based upon salmon, crabs, and shrimp.

Geology

The geology of the Cook Inlet Estuary cannot be separated from the geology of the region surrounding the waters. For that reason, the geology description will be expanded beyond the normal scope of this report. The major characteristic of the Cook Inlet area is that it is susceptible to earthquakes, being located in the trans-Pacific seismic zone.

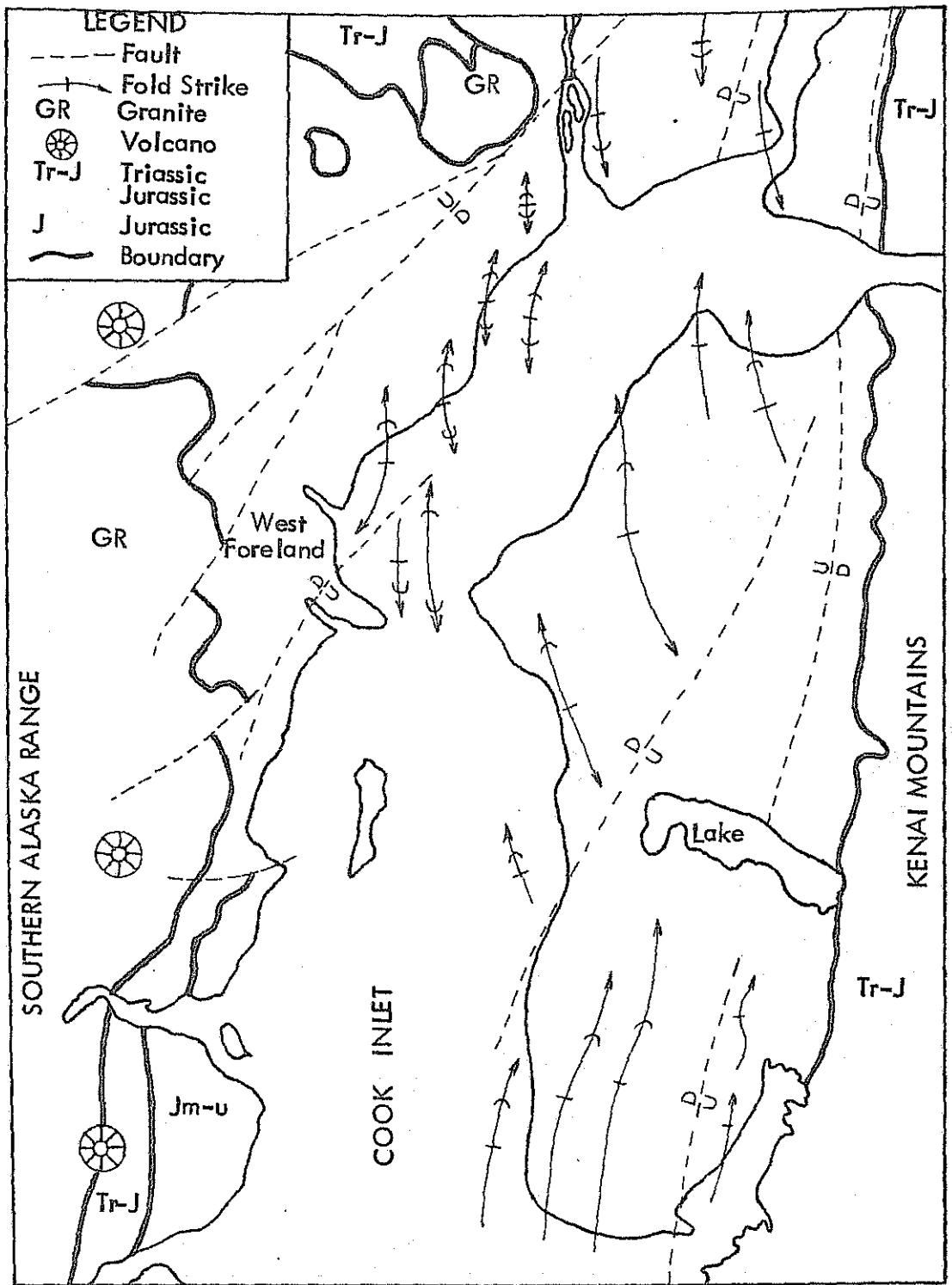
The Cook Inlet area is near the juncture of the western Pacific arc system and the orogenic belts of the western part of North America. Just northeast of Cook Inlet the trends of the mountain ranges abruptly change from northwest to southwest and extend in broad subparallel arcs. Near the apices of these arcs, the granite-cored Talkeetna Mountains separate the Chugach Mountains from the Alaska Range and form the divide between the head of Cook Inlet and the Copper River Basin to the east. Several fault zones have been mapped in central and southern Alaska; these in part follow and part transect the mountain range structure (Figure No. III-4). One of the faults, the Lake Clark-Castle Mountain fault, cuts the Alaska Range just north of Cook Inlet.

The geologic structure of the Cook Inlet area is highly complex. The rocks of the region record a history of repeated geosynclinal sedimentation deformation and intrusion beginning in the Paleozoic time and extending through the Tertiary. Near the end of the Cretaceous there was a downwarping and subsidence of the Cook Inlet trough and, in the Tertiary, rocks that are now locally more than 15,000 feet thick were deposited. By the end of the Tertiary time, the major topographic elements of the area were established. The subsequent geologic history has consisted largely of erosion and modification of mountainous areas during glacial and interglacial cycles and partial filling of lowland area and valleys with glacial drift and associated deposits. Offsets of surficial deposits along pre-existing faults in bedrock indicate continuing sporadic tectonism in the region through the quaternary and to the present. [57] The tectonic description of the Cook Inlet area will be discussed more fully later in this report.

Glaciation

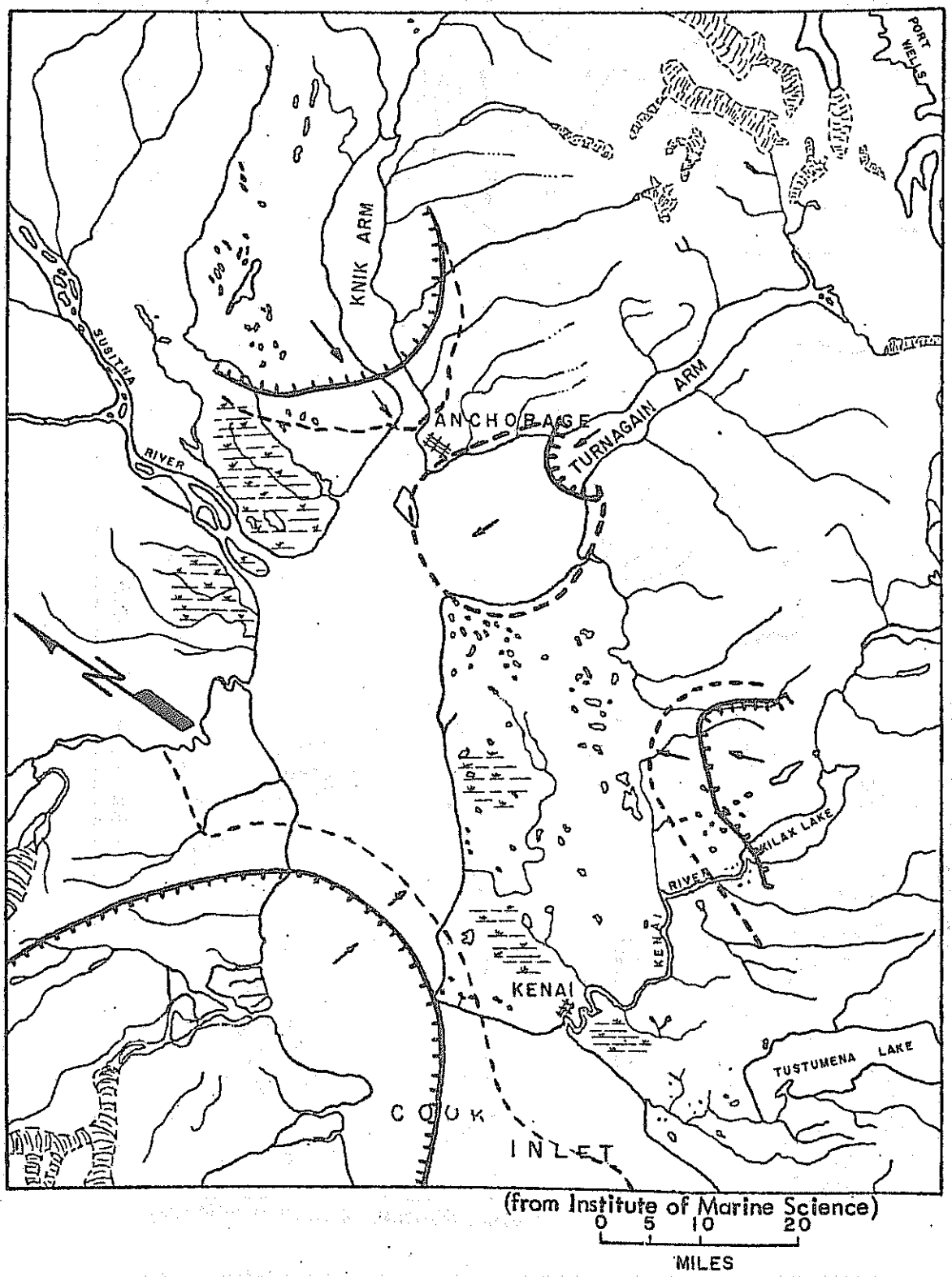
Five Pleistocen glaciations are recognized in the Cook Inlet area. All are represented by the depositional and erosional forms in the Kenai Lowland and the adjoining Kenai Mountains. These glaciations were named from type sections exposed on Mount Susitna in the Southern Lowland, in the Caribou Hills on the Kenai Lowland, in the Eklutna River valley north of Anchorage, along Knik Arm near Anchorage, and near the settlement of Naptowne (now called Sterling) along the Sterling Highway near Skilak Lake on the Kenai Lowland. Morainal evidence for a series of post-Pleistocenel glacial advances is found throughout the alpine mountain areas of the state. These advances are placed within the Alaskan glaciation of the Cook Inlet glacial chronology (Figure III-5).

FIGURE III-4



(from Institute of Marine Science)

PRINCIPLE GEOLOGIC AND TECTONIC FEATURES OF COOK INLET



(from Institute of Marine Science)

0 5 10 20
MILES

EXTENT OF KNIK (broken line) and NAPTOWNE (hatched line) GLACIATIONS
(after Karlstrom, 1964)

Mt. Susitna Glaciation. During this, the most extensive glaciation recorded in the Cook Inlet region, icecaps blanketed the surrounding Alaska Range and the Talkeetna, Chugach, and Kenai Mountains and completely filled Cook Inlet to elevations above 4,000 feet. This ice surface was apparently connected to glaciation in the Copper River Basin and Bristol Bay. The Cook Inlet ice in this and succeeding glaciations apparently spilled out to the Pacific Ocean through Shelikof Straits and the straits between Kenai Peninsula and Kodiak Island.

Caribou Hills Glaciation. During the Caribou Hills glaciation, Cook Inlet was again filled by ice emanating from the surrounding mountains. Lateral moraines attributed to the Caribou Hills glaciation rise to elevations of 2,000 to 3,000 feet along the eastern flanks of Mt. Susitna, on the flanks of the Talkeetna and Chugach Mountains and the Kenai Mountain Front. During this glaciation, the Caribou Hills area was completely covered with an ice sheet flowing out of the Harding Ice Field. From boulder count ratios, Caribou Hills ice began to retreat from the Skilak platform 155,000 to 190,000 years ago.

Eklutna Glaciation. During Eklutna time, ice covered the Cook Inlet basin for the last time. Trunk glaciers filled the Susitna, Matanuska, and Turnagain Arm valleys and coalesced with ice spilling off the Alaska Range and Kenai Mountains. Lateral moraines from Eklutna glaciation occur at 1,000 to 2,000 feet near the head of Cook Inlet and rise in elevation up the valleys. Eklutna ice almost completely covered the Caribou Hills area which acted as a barrier between the Kachemak Bay and Lower Cook Inlet glacier lobes. The Eklutna glaciation began its retreat from the Skilak platform some 90,000 to 110,000 years ago.

Knik Glaciation. During Knik glaciation, glacial lobes, draining major ice fields, extended into but did not coalesce to completely fill the Cook Inlet basin. Major ice lobes draining through the Kenai, Skilak, Killey, and Tustumena valleys from the Harding icefield coalesced to form a continuous ice shelf 25 miles wide and 50 miles long parallel to the Kenai Mountain front, north of the Caribou Hills. Coalescence of the Kachemak Bay lobe with the ice from the Aleutian Range created an interior lake during extended phases of Knik glaciation. The level of this interior lake is believed to have been at about 1,000 feet elevation. Retreat of this glaciation began some 50,000 to 65,000 years ago.

Naptowne Glaciation. The youngest major glaciation recognized in the Cook Inlet area is the Naptowne. During Naptowne time, ice from the Harding Icefield expanded northward filling the Kenai River and Resurrection Creek valleys with ice to elevations of more than 1,000 feet. The Tustumena Lake trough was completely filled with ice and extended to more than 30 miles from the Kenai Mountains front. Ice from the Alaska and Aleutian Ranges extended eastward across Cook Inlet to near Anchor Point and the East Foreland. The Naptowne glaciation was at its

maximum approximately 25,000 years ago.

Post Naptowne Glaciation. There have been two post-Naptowne glacial periods which are evidenced by fresh-looking moraines lying between the modified moraines of the Naptowne age and existing glaciers of today. Two separate advances are indicated, both called the Alaska Glaciation. The oldest of the two, named the Tustumena, advanced and occurred approximately 3,200 to 5,500 years ago. The youngest, named Tunnel, advanced 500 to 1,500 years ago. Minor readvances have occurred as late as 1950. [92]

Earthquakes

Southern Alaska and the adjoining Aleutian chain constitute one of the world's most active seismic zones. Extending from Fairbanks on the north to the Gulf of Alaska on the south, the Alaska seismic zone is but a part of the vast near-continuous seismically active belt that circumscribes the entire Pacific Ocean basin. Between 1899 and May 1965 seven Alaska earthquakes have equalled or exceeded Richter magnitude 8, and more than 60 have equalled or exceeded magnitude 7. About seven per cent of the earthquake energy released annually on the globe originates in the Alaskan seismic zone.

This highly active zone is circumferential to the Gulf of Alaska and parallel to the Aleutian Trench. It embraces the rugged mountainous region of southern Alaska, Kodiak, the Aleutian Islands, and the continental shelf and the continental slope of the Aleutian Trench. Most of the earthquakes originate at shallow to intermediate depths -- mostly less than 50 km -- between the Aleutian Trench and the Aleutian Volcanic Arc. Foci are generally away from the trench toward the arc. [71]

Good Friday Earthquake. Late in the afternoon of March 27, 1964, one of the greatest geotectonic events of our time occurred in southern Alaska. Half of Alaska was rocked and jarred by the most violent earthquake to occur in North America this century. This earthquake has become renowned for its destructiveness, long duration, and great breadth of its damage zone. Its magnitude has been computed by various observers to range from 8.3 to 8.75 on the Richter Scale. Few earthquakes in history have been as large. Thousands of people were made homeless, 114 lives were lost, and the economy of the entire state was disrupted. Seismic sea waves swept the Pacific Ocean from the Gulf of Alaska to Antarctica.

The epicenter of the earthquake was located at the head of Prince William Sound on the south flank of the Chugach Mountains about 80 miles east-southeast of Anchorage. The hypocenter, or point of origin, was at a depth of 20 to 50 km. The duration of the earthquake has to be estimated because of lack of instrumentation, but observers fixed the duration of the shock at three to four minutes.

An area of at least 70,000 square miles, and possibly 110,000 square miles, was tectonically uplifted or depressed during the earthquake. Much of Cook Inlet was in an area of general subsidence and a section of Kamishak Bay is believed to have been uplifted.

Earthquake damage to the cities, towns, and villages of Cook Inlet was caused by direct seismic vibration, ground breakage, mud or sand emission from cracks, ground lurching, subaerial and submarine landslides, fires, seawaves, and land level changes. Overall, landslides probably caused the most damage to man-made structures and seawaves took the most lives.

Anchorage, because of its size, bore the brunt of property damage, but many small villages outside the Cook Inlet area suffered more deaths than Anchorage. Many of the villages lost a sizeable portion of their population and some were completely destroyed. [71]

Effect on Anchorage. Damage was caused by direct seismic vibration, by ground cracks, and by landslides. Direct seismic vibration afected chiefly multistory buildings and buildings having large floor areas. Most small buildings were spared. Ground cracks caused damage throughout the Anchorage Lowland. Landslides caused the most damage and were attributed to the failure of Bootlegger Cove Clay, which, under vibratory stress of the earthquake, failed along a zone of low shear strength. The Bootlegger Cove Clay is a glacial estuarine-marine deposit underlying much of the Anchorage area. [70]

Effect on Homer. The earthquake shook the Homer area for about three minutes, causing a two to six foot general subsidence of the mainland and Homer Spit, and earthflow, and several landslides on the Homer Escarpment. The greatest damage was to Homer Spit, a four-mile long gravel and sand bar intruding into Kachemak Bay. After the earthquake and resulting tectonic subsidence, much of the spit was below high tide levels. A submarine landslide at the end of the spit destroyed much of the harbor breakwater. [194]

Ground Breakage in Cook Inlet Area. The earthquake caused considerable ground breakage in the Cook Inlet area. The breakage occurred mostly in thick deposits of unconsolidated sediments. The principal area of ground breakage in the Cook Inlet area was in a northeast trending zone 60 miles long and six miles wide in the northern part of the Kenai Lowland. Cracks were as much as 30 feet across and 25 feet deep.

A few avalanches and slumps occurred along the coast of Cook Inlet and tidal flats were cracked. Observations along the coasts indicated changes in sea level which, although caused partly by compaction

of unconsolidated sediments, may largely be attributed to crustal deformation accompanying the earthquake. Most of the Cook Inlet area was downwarped, although the northwest side may have been slightly upwarped. Maximum change in the Cook Inlet area was probably less than six feet. [57]

Earthquake Effects on Hydrologic Regimen. The 1964 earthquake greatly affected the hydrology of South central Alaska. Groundwater was drastically affected in unconsolidated aquifers for at least 160 miles from the epicenter. Lake and river ice was broken for distances of 450 miles from the epicenter by seismic shock and seiche action. The surging action temporarily dewatered some lakes. Landslides and avalanches temporarily blocked streams and rivers, in some cases diverted them permanently.

Within 100 miles of the epicenter, including the upper section of Cook Inlet, vast quantities of sediment-laden water were ejected into flood plains of glaciofluvial valleys. Subsidence was also common near submarine landslides and was probably caused by loss of water pressure and spreading of sediments.

Deep aquifers in unconsolidated sediments, which in most cases were under high hydrostatic pressure, were also greatly affected. Post-earthquake water levels for a year were compared with longterm prequake levels to show permanent changes in an aquifer system. At Anchorage and parts of the Kenai Peninsula, artesian pressure levels dropped as much as 15 feet. Seismically induced pressure on groundwater was instrumental in causing most of the disastrous slides. Water quality was not changed except for temporary increases in turbidity in wells and streams. [192]

Climatological Characteristics

The Cook Inlet climate is moderated by the mountain ranges surrounding the basin. These mountain barriers prevent the area from having the temperature extremes of the interior of Alaska and the heavy precipitation of the regions along the Gulf of Alaska. Data from weather stations at Anchorage, Palmer, Kenai, Homer, Bear Cove at the head of Kachemak Bay, Kasilof, and Iniskin in Kamishak Bay will be used in describing the characteristics of the Cook Inlet climate in the following section. Because of the commercial importance and amount of activity, the climate of Anchorage will be discussed separately.

Anchorage Area. Winters are not extremely cold and rain during December is not uncommon. Summers, as measured by the length of growing season, average about 135 days. The highest Weather Bureau temperature recorded is 86°F. (June 1953) and the coldest is -38°F. (February 1947).

The mean monthly temperature is 35°F. with summers averaging 55°F. and winters averaging 20°F. Cold spells with temperatures about -20°F. to -30°F. are usually short.

Anchorage is semi-arid -- the mean annual precipitation is only 14.71 inches, which includes a mean snowfall of five feet. About one-half the annual precipitation falls in a three-month period between July and September. September has the greatest rainfall with 2.71 inches and December the greatest snowfall with 12.4 inches.

Winds in the Anchorage area are generally from the northeast and usually are light (Table No. III-2). This results from the facts that air movement is usually from the relatively cold ice-capped mountains to the warm Inlet waters and that strong outside winds are blocked by these same mountains before reaching the metropolitan center.

Cook Inlet Area. Palmer, at the head of Knik Arm, is located within the Matanuska Valley. The climate of Palmer is similar to that of Anchorage with a growing season of 126 days. The average yearly precipitation equals 16.5 inches. Winds in the Matanuska Valley are quite variable. The stronger wind speeds are from narrow bands of cool air flowing out of the Matanuska and Knik Valleys and are oriented with the valleys. The directions vary only with the light winds.

Lower Inlet temperatures are quite similar to the upper inlet. The mean daily maximum temperatures in July, the warmest month, range from 60 to 64 degrees; the December mean daily maximum ranges from 20.3 to 22.9 degrees at Bear Cove, Iniskin, and Kenai and 27.7 degrees at Homer. The mean annual temperature range for Kenai, Kasilof, Bear Cove, and Iniskin varies from 33.1 to 34.4 degrees. Homer is warmer on the average than any of the other stations with a mean annual temperature of 36.4 degrees. The mean daily minimum temperature range for July is 43.2 to 46.1 degrees for all stations. The December mean daily minimum ranges from 3.5 to 7.2 degrees at Kenai, Bear Cove, and Iniskin, with Homer recording 15.5 degrees.

Precipitation varies considerably from one side of Cook Inlet to the other. Homer records a mean annual precipitation of 23.3 inches, Bear Cove records 25.8 inches, Kenai records 19.9 inches, and Iniskin in Kamishak Bay on the west side of the Inlet records 73.2 inches. Snowfall ranges from 53 inches at Homer to 69 inches at Kenai. Iniskin records almost 188 inches of snowfall, with traces of snow recorded in June and September.

At Kenai ice begins to form in the rivers and lakes during late November and becomes safe for man to travel on in early December.

TABLE III-2
AVERAGE MONTHLY WIND SPPED (mph)

	Merrill Field			International Airport			Elmendorf AFB
	24-Hour	Daytime	Nighttime	24-Hour	Daytime	Nighttime	24-Hour
January	5.0	4.6	5.1	5.2	5.3	5.2	4.7
February	5.1	5.6	4.9	6.8	7.0	6.6	5.3
March	4.6	4.9	4.3	6.1	6.4	5.8	5.4
April	4.8	5.3	3.9	6.7	7.0	6.2	5.4
May	5.9	6.6	4.0	8.8	9.1	7.9	5.7
June	5.5	5.9	3.9	7.7	7.9	7.3	5.4
July	4.6	4.9	3.5	6.8	7.1	6.1	4.7
August	4.2	4.6	3.5	5.9	6.1	5.4	4.3
September	4.4	4.9	3.7	5.2	5.6	4.6	4.2
October	4.4	4.9	4.1	5.1	5.2	4.9	4.7
November	5.0	5.0	5.0	4.9	5.0	4.9	4.7
December	4.2	4.0	4.2	4.7	4.8	4.7	4.1
Year	4.8	5.1	4.2	6.2	6.4	5.8	4.9

From: Tryck, Nyman & Hayes [184]

Breakup normally begins about the first of April. During the summer months a wind trajectory over the water keeps Kenai temperatures cooler than those recorded inland, reflecting a mild marine climate; however, the rest of the year is characterized by continental influences. From September to April temperatures average about five degrees colder than Homer to the south and Anchorage to the north. Surface winds, because of the channeling effect of Cook Inlet, prevail from a northern direction during the fall, winter, and spring months and from the south during the summer. Strongest winds are from the north, with speeds exceeding 25 m.p.h. about one per cent of the time (see Table III-3). It is probable that winds just offshore from Kenai reach velocities of 50 to 75 m.p.h. once or twice during each winter season. (U.S. Weather Bureau)

Estuary Characteristics

The general characteristics of the Cook Inlet area, including the surrounding land masses and the waters of the Inlet, were previously described. The Inlet waters are influenced by environmental changes in the surrounding areas brought about by natural ageing, population pressures, and seismic disturbances. The following section will describe the important characteristics of the waters of the Inlet, and will include the physical and chemical characteristics, tides and currents, sea ice, and sediment characteristics. The biota of the Inlet will be described in a following section.

Physical and Chemical Characteristics. The waters of Knik and Turnagain Arms, and, in turn, the waters of the upper Cook Inlet, are influenced seasonally by the great variation of fresh water inflow from the Susitna, Matanuska, and Knik Rivers, and to a minor extent by the Beluga River and Portage Glacier outwash river. The Susitna and Knik Rivers probably contribute 70 to 80 per cent of the total fresh water entering the Inlet (Table No. III-4). The maximum period of runoff occurs during the months of July and August. During this high runoff period much silt is carried into the head of Cook Inlet and the marine environment of Knik Arm approaches that of a fresh water regime. During winter months there is little or no flow and salinity values approach that of oceanic waters.

Oceanographic cruises of the Institute of Marine Science during July of 1966 and 1967 indicated that the characteristic salinity feature is a bending of the isohalines as a result of high salinity water on the eastern side and low salinity water on the western side of the Inlet (Figure III-6). This is attributed to the greater flow of fresh water prevalent at this time of year on the west side and to the coriolis forces. The salinity patterns present on the water surface continue with depth, indicating no vertical stratification. Salinity values for this period ranged from 31 o/oo (parts per thousand) at the mouth to 10 o/oo at the entrance to Knik Arm.

TABLE III-3
WINDS AT KENAI FOR CASES EXCEEDING 12 KNOTS (13.8 mph)

	Total No. of Cases per year	Average Wind Speed (kts)	Average Duration (hrs)
N	46	16	10
NNE	33	15	9
NE	4	14	5
ENE	2	14	5
E	0.3	16	4
ESE	0	0	0
SE	1	17	6
SSE	8	16	8
S	16	16	8
SSW	13	18	7
SW	2	13	5
WSW	0.3	25	5
W	1	17	3
WNW	0	0	0
NW	0	18	13
NNW	4	19	9
Jan	15	17	5
Feb	10	16	7
Mar	12	18	14
Apr	15	16	7
May	13	15	7
June	9	16	5
July	6	13	6
Aug	8	16	9
Sept	10	14	7
Oct	12	16	6
Nov	12	19	9
Dec	8	17	7

From: Tryck, Nyman & Hayes [184]

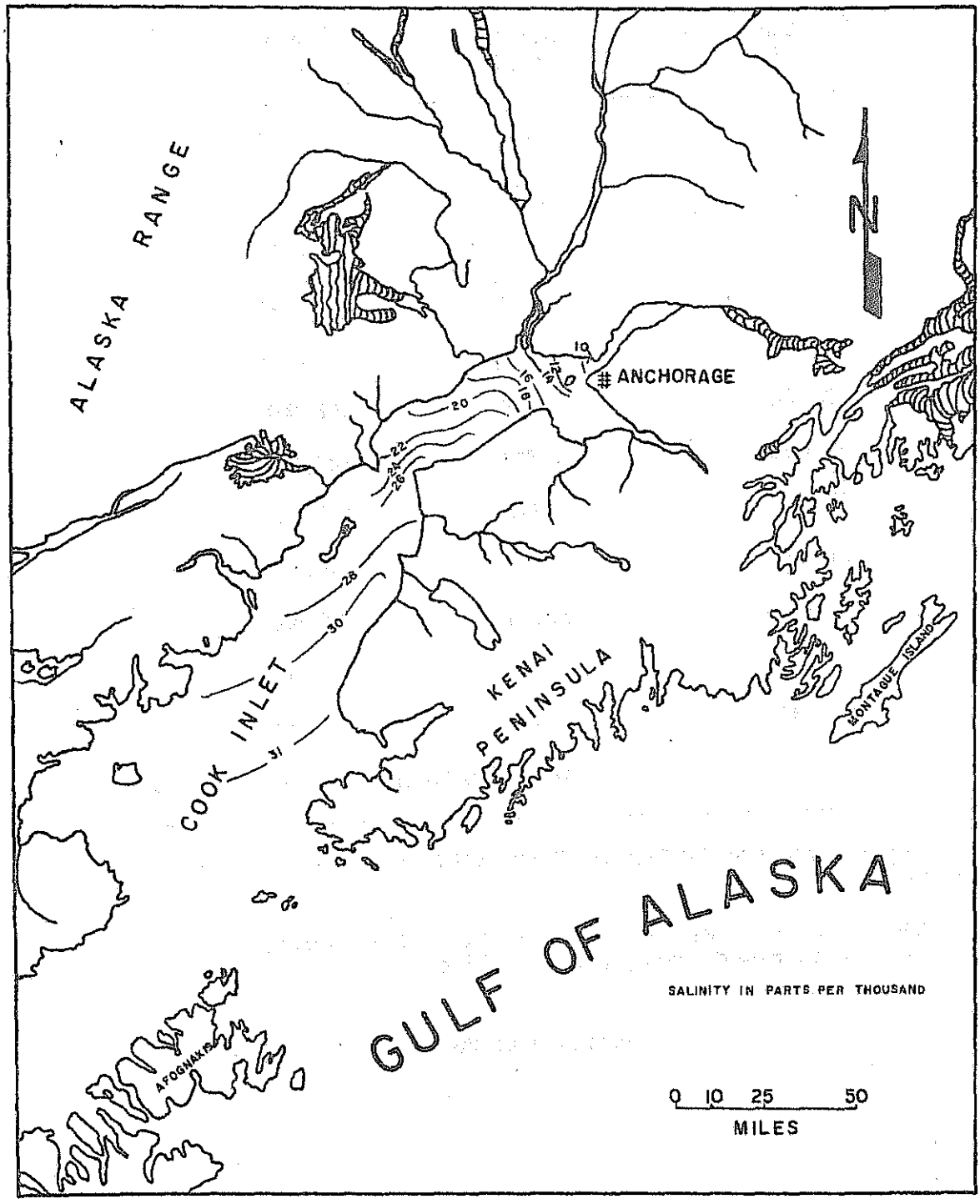
TABLE III-4
RIVER FLOW DATA - COOK INLET

Month	Susitna River* (cfs)	Knik Arm** (cfs)	Total (cfs)
January	4,776	1,559	6,335
February	3,906	1,309	5,212
March	3,285	1,031	4,316
April	3,970	1,497	5,467
May	46,066	5,675	51,741
June	83,186	18,932	102,018
July	80,058	43,639	123,697
August	77,799	33,446	111,245
September	51,533	17,279	68,832
October	19,957	5,895	24,852
November	8,586	2,858	10,307
December	6,044	1,950	7,994
		Mean flow/year	4.36×10^4 cfs

* Values are 3.186 times the average monthly means for the measuring station at Gold Creek

** Represents monthly mean flows for Eagle River, Chester Creek, Matanuska River, Cottonwood Creek, and Knik River.

FIGURE III-6



SALINITY RANGE OF COOK INLET WATERS

During the month of July 1966, the upper Inlet waters showed temperature patterns similar to the salinity patterns.
No pattern was found in the lower Inlet; the temperatures ranged from 9° to 10°C. The upper Inlet temperatures ranged from 10°C at the forelands to 14°C near the mouth of Knik Arm. This would be expected as the high saline oceanic waters are colder than the incoming fresh water which reaches temperatures of 13°C to 14°C during the summer months. There was an indication that during August a slight reversal of the upper Inlet temperature pattern was caused by a warming of the oceanic waters.

During a 1967 sampling cruise, nutrient chemistry data was obtained. Values were determined for nitrate, nitrite, phosphate, and ammonia. pH values were also determined.

Nitrate values within the Inlet generally were higher than those found in the oceanic region around Kodiak Island. Average values for nitrate within the Inlet ranged from 5.0 to 6.0 μg/l compared to oceanic values of around 4.0 μg/l. Kodiak Island values were less than 1.0 μg/l.

Nitrite values increase toward the mouth of the Inlet reaching a maximum of slightly less than 0.2μg/l. Nitrate values within the Inlet near the ocean were higher than those found withiin the ocean itself.

Phosphate values, like the nitrite values, increase toward the mouth of Cook Inlet from approximately 0.6 μgA/l to 1.5 μgA/l. Oceanic values range from 0.4 to 0.6 μgA/l.

Ammonia nitrogen values are low within the Inlet compared to oceanic values of 0.5 to 1.5 μgA/l. Ammonia Values increase from 0.0 in the upper Inlet to approximately 1.4 μgA/l. near the mouth. In general the pH of Inlet waters increases seaward from a value of 7.6 near Anchorage to normal ocean values of 8.4 at the mouth. [64]

In general, the amount of total nutrients increases near the oceanic regions of the Inlet, resulting in higher productivity. The low nutrient values in the upper Inlet may be the cause for the absence of plankton, although sediments may have a large effect in reducing the light penetration in this region. The conditions in the upper Inlet of temperature, salinity, and turbidity appear to be detrimental for plankton productivity.

Tidal Characteristics and Currents. The tides in Cook Inlet are semi-diurnal in nature with a marked inequality between successive low waters. The mean diurnal tide range varies from 13.7 feet at the mouth to 29.6 feet at the City of Anchorage on Knik Arm (Table No. III-5). Time between high water at the mouth and high water at Anchorage is approximately 4.5 hours.

TABLE III-5
COOK INLET TIDES IN FEET

Datum Plane	Kenai (Lower Cook Inlet)	Anchorage (Upper Cook Inlet)
Highest Tide	26.00	35.80
Mean Higher High Water	20.70	29.60
Mean High Water	19.90	28.90
Mean (half) Tide Level	11.05	15.55
Mean Low Water	2.20	2.20
Mean Lower Low Water	0.00	0.00
Lowest Tide	-6.00	-4.90
Mean Range	17.70	26.70
Diurnal Range	20.70	29.60
Extreme Range	32.00	40.70

Institute of Marine Science [22]

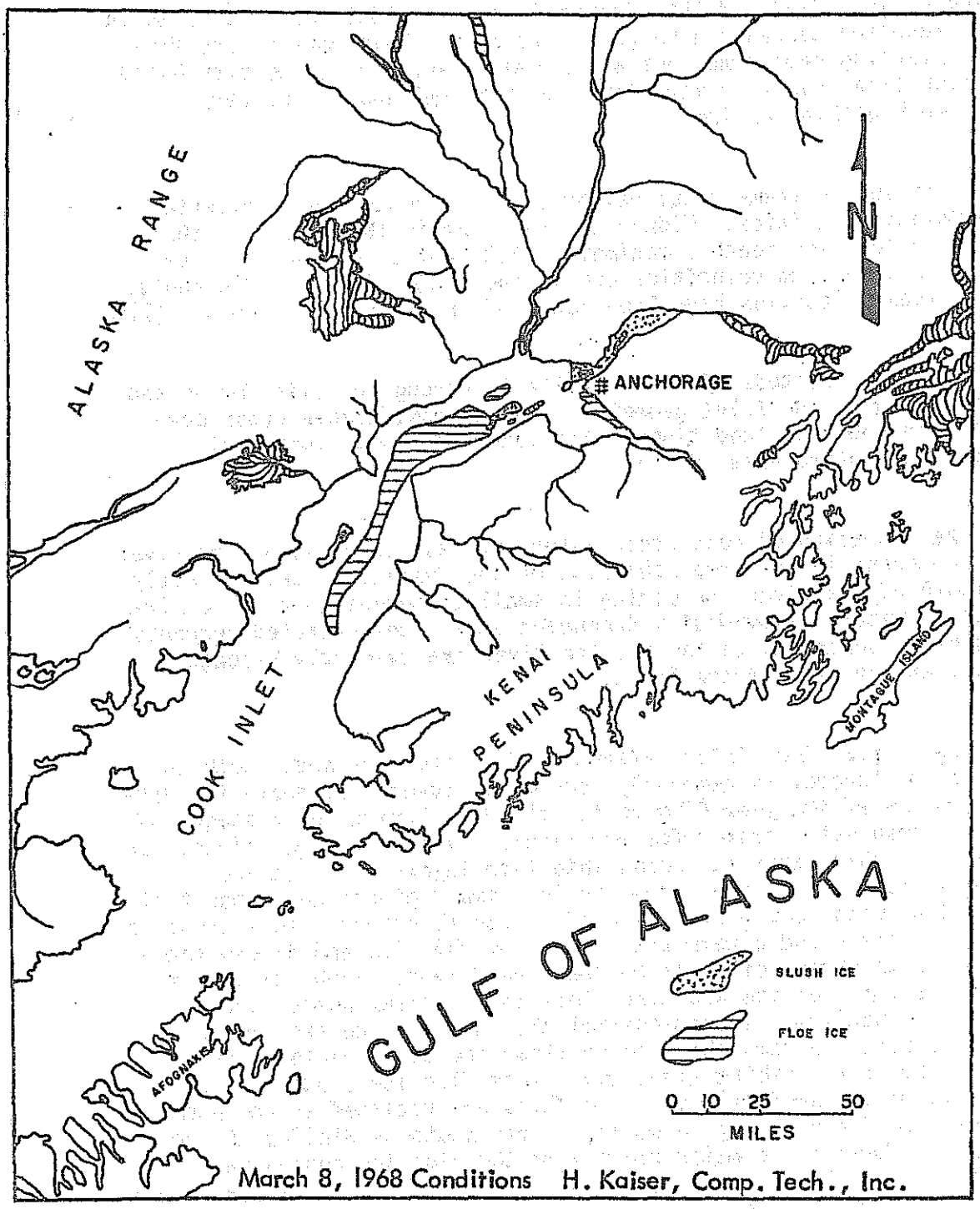
The tides within the lower portion of the Inlet have a mean diurnal range on the east side of 19.1 feet and a mean diurnal range on the west side of 16.6 feet. Within Turnagain Arm, a tidal bore occurs which has been reported to reach a height of 10 feet. This bore occurs frequently, starting some time just after low water. It may be attributed to the high tidal range, river flow into the Arm, and to the very shallow depth within the Arm.

With such extreme tidal heights, the currents may be expected to reach moderate velocities. Midway up the Inlet in the region of the Forelands, velocities reach a maximum of 3.8 knots. Elsewhere above these narrows, maximum velocities are in the range of 2.8 to 3.0 knots. In local areas velocities have been reported in excess of 5 knots. [114]

The high latitude of 62°N results in strong coriolis forces and this, coupled with the Inlet geometry, causes considerable cross currents at both ebb and flood tides. The water is always turbulent throughout the entire water depth. [22]

The intrusion of cold ocean water and its mixing with warm river water is apparent in the area southwest of the Susitna River. Directly at the mouth of the river the mixing is small or nonexistent. The mixing of Inlet waters is evidently dependent upon tide-generated currents. Tidal currents southwest of the Susitna River are evidently stronger than those at the head of the Inlet.

Ice. Upper Cook Inlet, extending from the Forelands north to the Port of Anchorage, is generally completely covered by heavy ice during four months of the year (Figure No. III-8). During lower stages of the tides, fresh water from tributary rivers covers the tidal flats. In winter months, this water is frozen into thin layers of sheet ice. Flood tides pick up this ice, break it into small pieces and reposit it upon the flats with some pieces stacked on top of others. This cycle is repeated many times and alternating layers of thin ice and frozen sediments up to a thickness of 15 to 20 feet are formed. High tides then pick up these cakes of ice and carry them to midstream where current velocities are maximum. In mid-channel the cakes of ice are broken up and reconsolidated to form the floe or float ice so characteristic of the Cook Inlet area. Ebbing tides carry this floe ice south to the restriction caused by the Forelands. The floes are retained in the upper Inlet with some ice escaping to points as far south as Ninilchick and Anchor Point. However, a major portion of the floe ice concentrates on the north side of the Forelands where it is frozen into large ice sheets. The bulk of the sea ice which is formed in the Inlet consolidates into floes. The ice of the Inlet has a net seaward movement with ice growth conditions prevailing in upper Cook Inlet and ice degradation prevailing in lower Cook Inlet. Thus, the thickest ice is found in the Forelands



ICE CONDITIONS DURING WINTER

vicinity. The retention of ice floes in upper Cook Inlet is found to be approximately 28 days and ice floes have a net seaward movement of 2.5 miles per day. The motion of the ice in the Foreland vicinity was observed to be generally in the tidal direction at high tidal velocities, but rotation flow occurs near slack tides. In addition to movement by tidal currents there is the obvious effect of wind forces. The thickness of ice formed in the Inlet depends on many variable factors of which atmospheric temperature plays a significant role. An ice thickness greater than six feet has been observed near the Forelands; however, this may have resulted from rafting, brush piling, and jumbled masses of slush and broken ice.

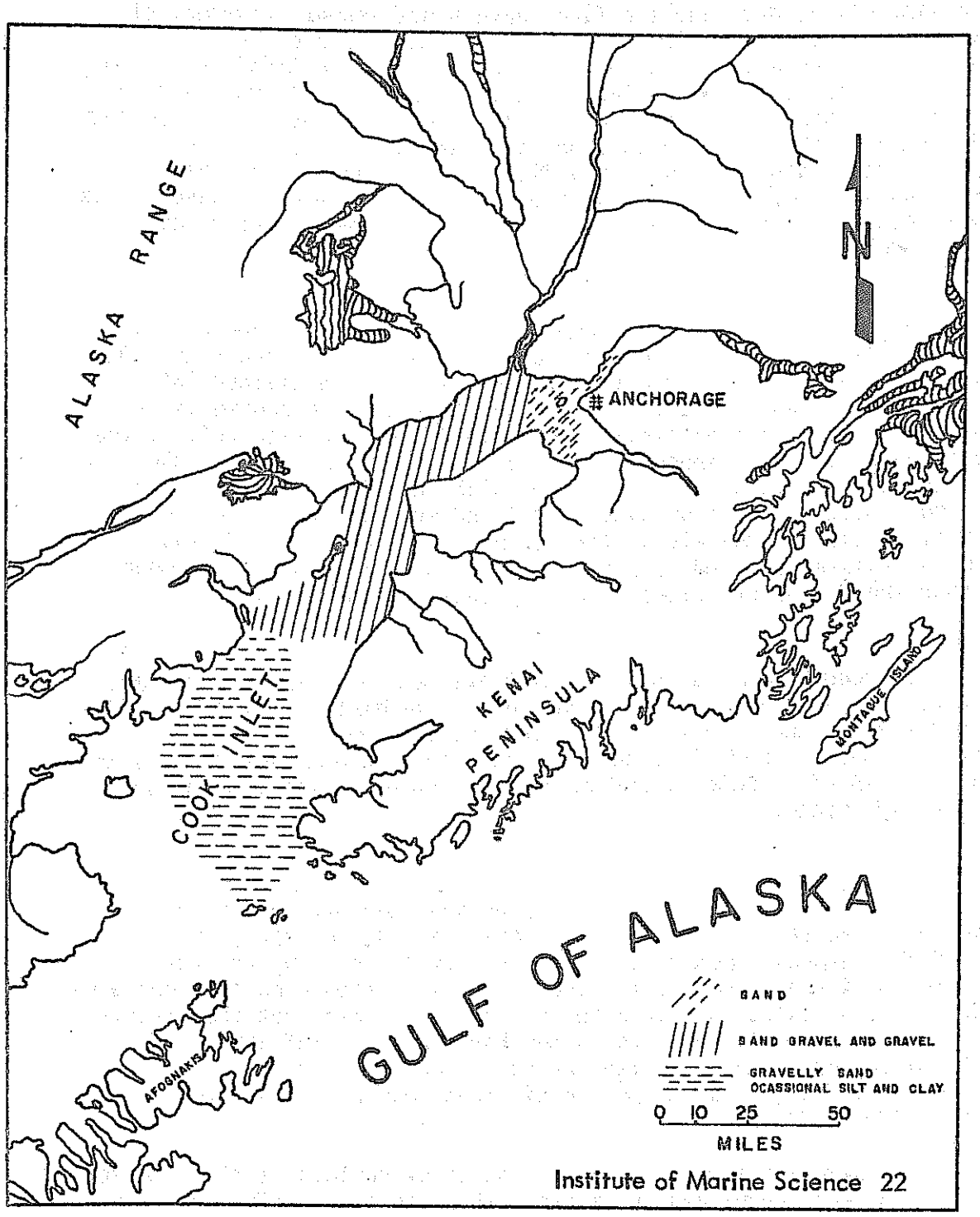
Sediments. Cook Inlet bottom sediments consist predominantly of cobbles, pebbles, and sand with minor proportions of silt and clay. On the basis of grain-size distribution, Cook Inlet can be divided into three depositional environments (Figure No. III-9). The sediments in each environment exhibit particular characteristics and also reflect the type and energy of the transporting media. In the lower part of the Inlet they comprise mainly gravelly sand with occasional silt and clay; middle Cook Inlet consists of sand-gravel and gravel; and in the upper part, east of the Susitna River, the sediments are composed of sand. Changes in grain-size parameters of the sediments from one environment to another are an abrupt, rather than a gradual, transition.

Suspended sediments in Cook Inlet are mostly of glacial origin. The highest concentrations of sediment were recorded near the mouths of the Susitna River and Knik Arm. Sediment loads exceed 2 g/l at the head of the Inlet. There is a tendency for the sediment load to be a maximum at a depth of 10 meters, and to have a greater concentration during the flood tide stage.

Explanations for the complex and unusual sediment distribution in Cook Inlet include effects of tidal action and hydrography, the nature of the suspended material, the effect of ice rafting and ice cover, and the bottom topography. The greatest influence on sediment distribution in Cook Inlet is attributed to tidal currents, but the distribution and character of sediments in the Forelands are influenced by ice rafting and by rivers. During the summer months, and particularly during abnormal floods, large amounts of gravel may be transportedby river currents. [22]

The winter ice formed in upper Cook Inlet contains a significant amount of sediment sandwiched in layers within the ice; surface melting during warm intervals leaves a very thin layer (0.01 inch) of mud. It has been noted that the Inlet ice area clears rapidly with the onset of warm weather. In one observed instance, when the temperature at Anchorage rose to above 27°F, the Inlet became virtually clear of a one-foot

FIGURE III-8



SEDIMENTARY FACIES OF COOK INLET

layer of ice within two or three days. Given such rapid melting rates, the deposition of ice-rafted materials may be significant. [22]

The presence of gravel in the Forelands area is also a function of the extremely strong currents passing through the Forelands constriction. This has the effect of churning up bottom sediments and removing suspendable solids. With the great turbulence quite large sediment particles may be removed from the Forelands area. As the distance from the Forelands increases, the energy of the water decreases. The sediment load in suspension decreases and sediments are deposited on the bottom in a graduated pattern. The grain-size distribution becomes a function of the distance from the Forelands. This gradated pattern is similar north and south of the Forelands due to flood and ebb tide currents.

Coriolis forces tend to confine the incoming waters to the eastern margins of the Inlet, and the confinement of coarser bottom material to this area has been noted.

THE BIOTA OF COOK INLET

Cook Inlet is the spawning ground for many species of fish and marine crustaecia, and the habitat of many types of estuarine flora and fauna. Tidal currents and sediments restrict the biota to the lower section of Cook Inlet with very few forms of life being found in Knik and Turnagain Arms and Cook Inlet north of the Forelands area. Pintail ducks are the exception to this and many use the western shore adjacent to the Susitna Lowland and also the bogs and marsh lakes within the Susitna Lowland as nesting and feeding areas. The only form of marine life to be found in the upper Inlet is the anadromous fish as they pass through the silt-laden water on the journey to the spawning grounds in the rivers and creeks.

From the mouth of Cook Inlet between Cape Douglas and Cape Elizabeth to the Forelands at Nikiski, the Inlet waters portray a viable biologic picture. Although little is known of the micro-benthos and planktonic population, the populations of importance to commercial fishing have been documented.

Fish

Commercially important species in Cook Inlet are salmon, halibut, flounder, sole and sculpins. The salmon fishery contributes most to the Cook Inlet fishing economy. Between 1930 and the early 1950's, the King Salmon was important to the fishing economy. The early run of King Salmon is bound largely for the upper Cook Inlet drainage areas -- the Susitna, Beluga, and Matanuska. Later runs head for the Kenai and Kasilof Rivers.

Red salmon are generally considered to be the most valuable species in Cook Inlet. In recent years, the Inlet red salmon catch has been second largest in Alaska, coming only behind that of Bristol Bay. The major producing areas for this fish are the Kenai and Kasilof Rivers.

Coho salmon are normally four-year fish. During the 1930's the average Coho pack was 45,000 cases of 48 one-pound cans, and 1939 was a peak year; however, the production decreased to a low in 1959. Since 1959 the production has increased and 40,000 cases in 1964 were processed. Coho salmon run much later than other species in Cook Inlet, some reported as late as December.

Pink salmon, abundant during even-numbered years, were relatively unimportant during the 1930's, with about a 40,000 case average. Since that time the populations have increased, and in 1964, 188,000

cases were processed. The tremendous numbers of pink salmon that arrive biannually in Cook Inlet about July 20, can overwhelm processing facilities, especially if a strong run of red, chum, and pink salmon arrive simultaneously. Pink salmon utilize both large and small drainage basins for their spawning and are found in almost every suitable spawning stream in the Inlet. The Talachulitna River, a tributary to the Susitna, is the major producer above the Forelands, and the Kenai River the major producer in the lower Inlet.

Chum salmon are also four-year fish and have increased markedly in recent years. The 1964 chum pack was the largest ever packed in the Inlet, with a total of nearly 136,000 cases.

Between 1960 and 1965 the yearly total amount paid fishermen for the Cook Inlet-Resurrection Bay management area ranged between $2,338,359 and $5,204,620 for a six-year total of $19,753,680. The total for the previous six years of 1954 through 1959, was $14,671,825.

Shellfish

In the past few years, the shellfisheries of Cook Inlet have expanded at a rapid rate. The king crab, shrimp, and dungeness crab fisheries have become economically important. Other shellfish of potential importance are clams, tanner crabs, scallops, oysters, and abalone.

Alaskan king crabs are known to consumers throughout the world. They are harvested in lower Cook Inlet and in the vicinity of Kodiak Island, the proce-sing facilities being located at Kodiak. In recent years the king crab harvest has fallen off due to over-harvesting. Dungeness and tanner crabs have become more important and the crab industry has been expanding as the emphasis shifts to the latter species. [3]

Pink shrimp and side stripe shrimp appear in the Cook Inlet areas near Kachemak and Kamishak Bays and provide the shellfish industry with another commercially valuable species.

Razor clams are found on many surf-swept sand beaches of south-central Alaska. Many of these beaches, popular for the sport harvest of razor clams, are located along the eastern shore of Cook Inlet. These beach areas are located between the Kasilof River and Happy Valley on the coast of the Kenai Peninsula. The best digging areas are at Clam Gulch, 22 miles south of Soldotna, and at Happy Creek, 45 miles south of Soldotna. [129]

Birds

The Cook Inlet area contains habitat for migratory game birds of national and local significance. The habitat includes the Inlet, tidal river mouths, and the rivers and marshes adjoining the Inlet. These marshes exceed 100 square miles of area and include the habitat for many water birds.

Sea birds of importance are eiders, auklets, murres, guillemots, puffins, kittiwakes, gulls, terns, and cormorants. Chisik Island in Tuxidni Bay on the west side of Cook Inlet was established as the 6400-acre Tuxidni National Wildlife Refuge in 1909 to protect the abundant nesting birds inhabiting the island.

Birds such as bald eagles, crows, jays, ravens, shore birds, and passerine birds inhabit the shores and feed on the abundant supplies of food.

During the spring and fall migration these water and land birds reach spectacular abundance. The game ducks that use the Pacific Flyway fly through as well as nest and feed in both the upper and lower Inlet. Game ducks using this area include pintail, widgeon, grovelers, greenwing teal, mallards, and gadwalls. Other waterfowl using the area are whistling swans, trumpeter swans, Canada geese, white fronted geese, black brandt, and snow geese. [Bureau of Sport Fish and Wildlife]

INDUSTRIAL DEVELOPMENT AND EXPLOITABLE RESOURCES

Since the time when people started to settle the Anchorage area and the resource-rich valleys and mountains surrounding Cook Inlet there has been a constant demand for fuel and commercially valuable minerals. At present the dominant economic bases of industrial development in the Cook Inlet area are the natural resources of the region. Coal and petroleum are the two most important resources; however, in the past, gold and scarce minerals played important parts in the economy. Other valuable minerals have been found and their development awaits transportation access to the deposits.

Coal Mining

Coal reserves have been found over most of the State of Alaska. The three major types of coal found in the state are anthracite, bituminous, and subbituminous and lignite. Quite large deposits of bituminous and subbituminous coal have been found in the Cook Inlet area. With the construction and operation of the Alaska Railroad, beginning in 1914, coal deposits were needed adjacent to the railbelt. The Matanuska Valley coal fields were developed during this period. They contain the only deposits of high grade bituminous coal in the Cook Inlet area. Construction of Elmendorf Air Force Base and Fort Richardson in Anchorage, as well as fuel needs for homes, commercial power requirements, placed a demand for coal from these fields.

Coal beds in the Matanuska field contain interbedded impurities in the form of shale, clay, and bone. Sections of the deposits near Houston at the eastward side of the field are covered with pressurized gas and brackish water. Estimated reserves for the Matanuska field are placed at 201,000,000 short tons of bituminous and 1,000,000 short tons of subbituminous coal. Production through 1958 was 4,800,000 short tons. With the development of the natural gas fields in the Swanson River area it is anticipated that the City of Anchorage and the military bases will convert from coal to natural gas. [126, 90]

Numerous outcrops of coal are reported on the Kenai Peninsula in the vicinity of Homer. The Kenai coal formation extends north of Homer along the north shore of Kachemak Bay and also along the shore of Cook Inlet as far north as Kasilof and Kenai. The main coal formation contains several beds, and outcrops have been observed in gulches and valleys extending into the benchland in the Homer area. The formation consists of subbituminous coal, poorly consolidated sand, clay, and claystone. At the present time one coal mine is located near Homer. The estimated reserves in the Kenai formation are 2,400,000,000 short tons of which less than 1,000,000 short tons had been mined to January 1, 1959. [181]

Coal outcrops have been discovered in the Susitna Lowland in the vicinity of the Beluga and Yentna Rivers. This coal formation is very likely an extension of the Kenai formation. The Beluga-Yentna beds occur in a large but undetermined number of beds ranging from a few feet to more than 50 feet in thickness, interbedded with claystone, siltstone, sandstone, and a conglomerate of the Kenai formation. Little is known of the extent of the bed, but reserves are estimated at greater than 2,400 million tons of subbituminous coal of which 2,100 million tons are concentrated in an area of 400 square miles in basins of the Beluga and Chuitna Rivers. These reserves are arbitrarily limited to coal under less than 1000 feet of overburden and within a half mile of measured outcrops, except in beds of known greater extent. [9]

The Petroleum Industry

The discovery of oil and gas in commercial quantities in the Cook Inlet basin over the past eleven years, and the recent discovery of oil on the north coast of Alaska have stimulated the development of Alaska in a way that is unprecedented in the history of the area.

History. The Swanson River oil field was discovered on the Kenai Peninsula (approximately 50 miles southwest of Anchorage) on July 19, 1957. Within a few years after its discovery the Swanson River field was in commercial production, and by January 1, 1966, oil production totaled 50,259,164 barrels. There are now 58 oil wells over two miles deep in the area; in addition, 11 gas wells are in production.

In 1963 oil of commercial importance was discovered near middle Ground Shoal in Cook Inlet. It has been revealed that the earth beneath the Inlet waters contains at least four oil fields with prospects of several others existing. Many large, permanent, all-weather drilling platforms have been positioned in Cook Inlet and in 1964 a dual pipeline capable of carrying 100,000 barrels of oil per day was completed from the platforms to storage facilities on shore. Production from wells located in Cook Inlet began in December 1965 at a rate exceeding 1,000 barrels per day per well (Table III-6). [184]

1967 Summary. Development drilling in 1967 was centered mainly on the drilling platforms in Cook Inlet. Seventy-four development wells were active. Construction was completed on five additional offshore drilling-production platforms, making a total of eleven operational in Cook Inlet. In 1968, 14 platforms were in operation. Over 26 miles of dual pipelines were installed in Cook Inlet from platforms to shore. The 42-mile, 20-inch diameter common carrier pipeline was completed from Granite Point to the offshore Drift River loading terminal. The highest productive well was slightly over 9,200 barrels per day. Eight wells

TABLE III-6
STATE TOTAL PRODUCTION
Summary by Years

	Oil-Bbls.		Gas - MCF @ 14,65 psi & 60°F				Total
Year	Oil	Cumulative	Csg. Head	Cumulative	Gas Well*	Cumulative	Cumulative
Prior to 1958					829,832	829,832	829,832
1958	35,754	35,754	5,643	5,643	115,030	944,862	950,505
1959	186,590	222,344	27,291	32,934	132,624	1,077,486	1,110,420
1960	557,999	780,343	99,176	132,110	211,225	1,288,711	1,420,821
1961	6,326,501	7,106,844	1,293,258	1,425,368	387,155	1,675,866	3,101.234
1962	10,259,110	17,365,954	1,914,054	3,339,422	1,839,229	3,515,095	6,854,517
1963	10,739,964	28,105,918	2,808,011	6,147,433	8,213,056	11,728,151	17,875,584
1964	11,053,872	39,159,790	3,233,232	9,380,665	8,880,522	20,608,673	29,989,338
1965	11,128,545	50,288,335	3,842,367	13,223,032	8,701,080	29,309,753	42,532,785
1966	14,358,213	64,646,548	6,822,476	20,045,508	34,833,665	64,143,418	84,188,926
1967	28,917,446	93,563,994	22,539,948	42,585,456	40,360,557	104,503,975	147,089,431

*Includes gas from South Barrow Field - NPR4

State of Alaska Division of Mines & Minerals [48]

tested around 2,000 to 4,000 barrels per day. Total oil production for 1967 amounted to 28,917,464 barrels. Production increased from 51,500 barrels per day at the beginning of 1967 to 109,455 at the end of December. [48]

Oil Fields and Operators. There are eight major oil and gas producing fields in the Cook Inlet area. The major fields consist of the Middle Ground Shoal Field, the Granite Point Field, Swanson River Field, Trading Bay Field, McArthur River Field, Kenai Gas Field, Kenai Deep Gas Field, and the Sterling Gas Field. Major operators of these fields are Shell Oil Company, Pan American Petroleum Corporation, Mobil Oil Corporation, Standard Oil of California, and Western Operations, Inc., Union Oil Co. of California. Figure III-10 provides data on oil producing fields, locations, operators, number of wells, depth of producing fields, etc.

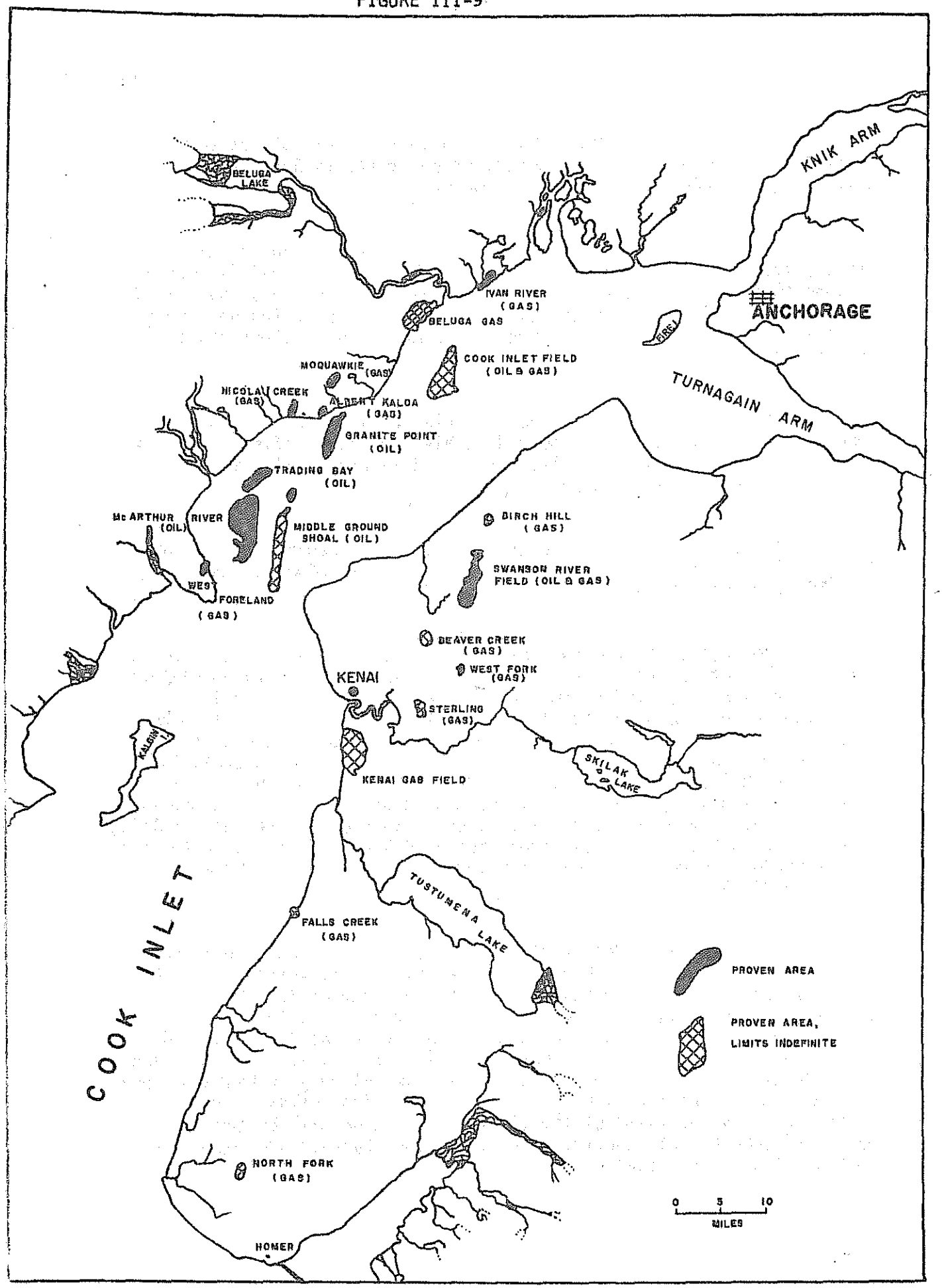
Manufacturing, Pipeline and Gas Utility Companies. With the oil production capabilities of the Cook Inlet area well established, various facilities for the transporting, refining, shipping and manufacturing have developed.

Cook Inlet Pipeline Company was formed by five oil companies; Mobil, Union Oil of California, Marathon, Atlantic Richfield, and Cities Service. It owns and operates a 42-mile pipeline and marine tanker loading terminal on the west side of Cook Inlet on a common carrier basis. The north end of the 20-inch line begins at the Mobil Oil Company's Granite Point treating facility. A Union-Marathon treating facility, Texaco and Superior, and Atlantic Richfield treating facilities will also tie into the 20-inch line.

The Kenai Pipeline company operates an 18.5-mile, 8-inch common carrier trunk crude oil line and a one-mile, four-inch feeder line, extending from the Swanson River Field to the Nikiski Terminal. This pipeline and the Kenai Pipeline Co., are owned and operated by Union Oil Co. of California and Atlantic Richfield. Kenai Pipeline also owns and operates a 16-inch gas pipeline that parallels the above described 8-inch lone. This 16-inch line is an extension of a 20-inch line that carries gas from the Kenai Gas Field to the Swanson River Field for repressuring. Union Oil of California and Marathon own and operate the 20-inch line. Kenai Pipeline Co. operates a 3.5-mile, 12-inch crude oil pipeline from an onshore facility to the Nikiski Terminal which carries Cook Inlet crude oil.

The Alaska Pipeline Company handles a 90-mile gas transmission line running from the Kenai Gas Field to Anchorage. The line has a capacity of 71 mcfd and gas is purchased under a 20-year contract with

FIGURE III-9



OIL AND GAS FIELDS IN COOK INLET AREA

Union Oil Company and Marathon Oil Co. Anchorage Natural Gas Corporation was formed to handle the distribution system in Anchorage as a joint project with Alaska Pipeline Company.

Kenai Utilities Services Corporation was awarded the gas utility franchise for the City of Kenai. The City of Kenai is served through 40 miles of buried transmission lines from the Kenai Gas Field. Kenai Utilities Services Corporation is owned by the Covington Corporation which also owns a hydrocarbon by-product asphalt plant adjacent to the Standard Oil Company of California's refinery.

The only crude oil refinery in Alaska is owned by Standard Oil Company of California and is located at Nikiski. The refinery supplys the Alaska market with jet fuels, diesel and furnace fuels, stove oils, distillate fuel oils, and asphalt.

In 1959, Union Oil Company of California acquired the Alaska Asphalt Plant. Included was a bulk plant in the terminal yards of the Anchorage City Dock.

The Collier Carbon and Chemical Corporation fertilizer complex is the first petrochemical plant to be built in Alaska. The 50 million dollar investment located on the shore of Cook Inlet at Nikiski is scheduled to go into operation in the latter part of 1968. This plant, producing 1500 tons of ammonia per day, will be incorporated with a 1,000 ton per day prilled urea plant. The ammonia plant is owned by Collier, a wholly owned subsidiary of Union Oil of California. The urea plant is jointly owned by Collier and Japan Gas Chemical Company, Inc. The facility will use 20 billion cubic feet of natural gas annually from the Union Oil Co. of California-operated Kenai Gas Field, with most of the production going to Japan and the West Coast of North America, including Alaska.

The 50 million dollar liquified natural gas plant now being constructed on the Kenai Peninsula at Nikiski will be completed in the late fall of 1969. In the summer of 1966 the contract for the sale of liquified natural gas (LNG) was signed between Phillips Petroleum Co. and Marathon Oil Co. and two Japanese firms, Tokyo Gas Co., Ltd. and Tokyo Electric Power Co. The contract calls for delivery of 50 billion scf (standard cubic feet) of gas per year with delivery to begin in 1969. Maximum capacity of the plant will be 172.6 million scf/day. Phillips Petroleum is the operator of the plant and Marathon will be the operator of two 440,000 barrel capacity tankers (440,000 barrels are equivalent to 1.5 billion cubic feet of gas). [4]

With the Cook Inlet area still in the stage of production and development, with greater demands for fuel and petrochemical products, and with large reserves of petroleum available, the petrochemical industry is expected to continue to grow in the Nikiski and Anchorage areas.

Undeveloped Mineral Resources of Importance. While coal and petroleum have played important roles in the past and present development of the Cook Inlet area, it is anticipated that, as transportation facilities develop and access to undeveloped areas of the land surrounding Cook Inlet is made available, commercially valuable deposits of chromite, marl, pumice and other minerals will be developed. References are made to copper, silver, gold, zinc, lead, molybdenum, graphite, chromite, marl pumice, diatomite, and iron as of possible future importance.

Chromite deposits have been found near Claim Point at the southern tip of the Kenai Peninsula. The lot of Chromite from the Claim Point are by assay was found to be readily amenable to production of high grade concentrates by ore dressing techniques. [166]

Chromite also occurs in two locations near the Anchorage-Palmer Highway in the Knik Valley. This ore is not high grade and the highest analysis showed a Cr_2O_3 content of 31.1 per cent and an iron content of 11.1 per cent, compared to an analysis of 49 per cent Cr_2O_3 for the Claim Point deposit. [15]

The occurrence of marl at several locations in the Knik Arm area has been known for many years. The most significant deposits are located near Wasilla, about 30 miles north of Anchorage. Other deposits have been found on the Ft. Richardson Military Reservation and near the east shore of Big Lake, 40 miles north of Anchorage. The marl is chemically suitable for the manufacture of portland cement, but the inferred reserves on one million tons would be insufficient for modern large scale operations. [143]

Three principal areas of pumice deposition have been found in the Alaska Peninsula-Cook Inlet area: Katmai National Monument, Augustine Island, and the Veniaminof-Aniakchak area. Mining was carried on by the Alaska Katmalite Corporation during the 1946-1949 period. The limited amount of data available indicate the deposits of chief interest occur in the valley of the Aniakchak River and in areas adjacent to Chignik Bay. [142]

Canneries and Shellfish Processors

Commercial fishing ranks second only to the petroleum industry in Cook Inlet. In 1967, approximately 2,400,000 salmon of all species were caught, equivalent to 14,573,000 pounds of fish. In addition, 3,109,542 pounds of King Crab, 7,168 pounds of dungeness crab, and 741,438 pounds of shrimp were harvested. [3]

Twenty canneries and shellfish processors operated in the Cook Inlet area in 1967 and 44 processors filed an intent to operate in the Inlet in 1968. The primary products of the canneries and shellfish processors are canned salmon, smoked salmon, fresh and fresh-frozen salmon, salmon roe (eggs), fresh and fresh-frozen king crab, and frozen halibut. Principal locations of processors are Homer, Anchorage, Seldovia, Kenai, Ninilchik, Kasitsna Bay (across Kachemak Bay from Homer), Kalifonski Beach (near Kenai), Kasilof, Soldotna, Clam Gulch, Beluga River, and Snug Harbor (west side of Cook Inlet on Chisik Island). In addition, one seagoing processor operated in Cook Inlet in 1967. The names, locations, and products of the individual processors operating in 1967 and intending to operate in 1968 are listed in the appendix to this report. (Bureau of Commercial Fisheries).

WATER QUALITY CONSIDERATIONS

When one thinks of the term "Water Quality", the thought of pollution is foremost in mind. However, water supplies are commonly withdrawn from surface water sources in lakes, streams and rivers. The impact on the quality and usability of these waters for human consumption as well as use for navigation, industrial use, recreation and other benefits must be kept in mind. It is the purpose of this section of the report to comment on the various Federal, State, and local laws pertaining to water quality and water pollution. The creation of the Federal Water Pollution Control Administration and the entrance of this agency into water pollution on a national scale has had a major effect on pollution abatement and the establishment of more stringent pollution control laws in every level of government. The adoption of the Alaska State Water Quality Standards into the Federal Water Quality Standards was a major step forward for Alaska.

It is not the author's intent to expressly describe each law relating to water pollution and quality but to mention them and fit the more important laws and standards into the proper perspective of water quality management and control. The effect of the newly adopted State Water Quality Standards on construction of waste treatment facilities in the Cook Inlet area is described and the affected facilities are listed on a table at the end of this section.

Water Quality Standards and Laws

In "A Water Code for Alaska, A Report to the State of Alaska" prepared by Frank J. Trelease, and submitted in 1962 to the Commissioners of the State, Mr. Trelease states: "Since 1947 Alaska has had a quite good Water Pollution Act. It could be improved in the light of the past 15 years of experience in Alaska and other states. There needs to be little change in the substantive law, but procedures could be improved, modernized and strengthened. If a comprehensive water code is to be adopted, the pollution laws must be fitted into it and their administration must be coordinated with the other water resources control of the State." [183] Since 1962, water pollution laws have become much broader and more strong both on the Federal and State levels. It is of interest to present the background of these and to place them in the context of the waters of Cook Inlet.

Federal Regulations. With the passage of the Water Pollution Control Act in 1948, the federal government took its first big step into what had been almost an exclusive area of state sovereignty although specific federal laws on pollution had been in existence before 1900. It primarily supplemented state and interstate efforts with the technical aid and services. Federal enforcement action was authorized but only in

interstate situations and with the consent of the states in which waste discharges causing water quality degradation were deemed to originate. In 1956 the act was rewritten. The new act strengthened federal enforcement action in connection with interstate water quality problems and introduced grants-in-aid to subsidize municipal waste treatment plant construction. The law also aimed to encourage state and interstate efforts by various means -- primarily subsidies for administration -- and it initiated a program of comprehensive water quality surveys.

The Water Pollution Control Act was amended again in 1961. Enforcement authority was broadened to include all "navigable" waters, and subsidies for the construction of municipal wastewater plants were increased. The 1961 Act also provided for the inclusion of storage in federal multipurpose reservoirs to augment low flows for water quality improvement.

The law was again amended in 1965. The 1965 Water Quality Act broadened federal jurisdiction through a provision requiring the establishment of standards of quality for all interstate waters. The states were required to set such standards (to be approved by the Secretary of Health, Education, and Welfare) by June 30, 1967, or face the imposition of federal standards. Federal subsidies for municipal waste treatment plant construction were once more increased. Also, a new agency -- the Federal Water Pollution Control Administration (FWPCA) was created to replace the U.S. Public Health Service Division of Water Supply and Pollution Control. This represented an effort to broaden and improve the status of the federal water quality effort. The FWPCA was subsequently moved from the Department of Health, Education, and Welfare to the Department of the Interior.

The most recent law is the Clean Water Restoration Act of 1966. The feature of primary interest is a further large increase in the federal subsidies available for municipal waste treatment facilities. It authorizes $3.4 billion for construction grants for the fiscal years 1968 through 1971. If certain conditions are favorably met, the federal share can now rise to as high as 55 per cent of capital costs. To provide incentives for developing comprehensive water quality planning for entire watersheds, the act offers assistance in the financing of such undertakings up to 50 per cent of the cost of the planning agency for a period of three years if it is requested by the relevant governors and certain conditions for representation are met. [97]

The "Oil Pollution Act of 1924" prohibits any person to discharge oil by any means from any boat or vessel into or on the navigable waters and adjoining shorelines of the United States. All oil discharges are to be removed immediately. The definition of "discharge" under the Oil Pollution Act of 1924 was narrowed when the 1924 Act was brought within

the framework of the Clean Water Restoration Act of 1966, and transferred from the authority of the Secretary of the Army. The original "Act" had prohibited any discharge of oil, by whatever means, into the navigable waters of the United States, except in cases of emergency and unavoidable accident. The 1966 amendment changed the definition of discharge to "any grossly negligent or willful spilling, leaking, pumping, pouring, emitting or emptying of oil". Thus fault must be shown on the part of the discharger of oil to the waters. [52]

Another law which does not require any showing of fault on the part of the discharger is Section 13, of the Act of 3 March, 1899 (33 U.S.C. 407), commonly referred to as the Refuse Act. This act holds that oil is refuse and cannot be discharged by any means. Section 17 of the 1899 act provides for the prosecution of offenders under the act when requested by the Secretary of the Army. The implementation of this act is contained in Reference 1145-2-301 of the Department of the Army, and is to be implemented by the Corps of Engineers Districts.

The major Federal Laws regulating pollution in the Cook Inlet waters are: (1) the Water Pollution Control Act (PL84-660) as amended by Pollution Control Act of 1961 (PL-87-88), the Water Quality Act of 1965 (PL 89-234) and the Clean Water Restoration Act of 1966 (PL 89-753), and (2) the Oil Pollution Act of 1924 as amended by the Clean Water Restoration Act of 1966 (PL 89-753), and (3) the Act of 3 March, 1899 (33 U.S.C. 407) known as the Refuse Act.

Alaska State Laws. The laws pertaining to water quality objectives, prevention of industrial waste pollution, sewage works, water supply and waste disposal were in effect before statehood in 1959. Section 526 (Policy) of Part 2., Subchapter 4., Water Pollution Control Water Quality Objectives states:

> It is hereby declared to be the policy of the Department of Health and Welfare to encourage and promote programs for the preservation of the surface and groundwaters of the state and the restoration of such waters to the best possible condition consistent with the public health and welfare, the propagation and protection of fish and wildlife and the domestic, recreational, agricultural, and insutrial development of the state.

The Alaska Administrative Code, Title 7, Division 1, Chapter 2, Sub Chapter 2, Section 302, prohibits the discharge of untreated or insufficiently treated sewage into any lake, and the above sewage includes all sewage, solid or liquid wastes from residences, business buildings, institutions and industries. No sewage is allowed to be discharged directly into any well that enters a water-bearing strata, or crevice,

sink hole or opening that will allow contamination of groundwater. Or:

> Whenever investigation by the commissioner of Health and Welfare shall show that the discharge of untreated or insufficiently treated sewage or industrial waste into a water-course or stream does produce conditions prejudicial to the public health, the person, persons, firm, corporation or the municipality discharging or permitting to be discharged any such untreated or insufficiently treated sewage or industrial waste into a water-course or stream shall, upon receipt of an official order from the Commissioner of Health and Welfare, immediately proceed with the construction of such works, or take such other steps as may be necessary to abate the conditions prejudicial to public health.

Prevention of industrial waste, pollution is handled by state statutes described in the Code, Title 7, Division 1, Chapter 2, Sub Chapter 4, Part 1, Sections 502, 503 which excludes waste materials resulting from waste prevention measures in specified industries from being discharged to any natural waters. The industrial waste includes any liquid, gaseous, solid or other waste substance resulting from any processes of industry, manufacturing trade or business or from the development of any natural resources. Gravel, sand, mud or earth taken from its original site and put through sluice boxes, dredges, or other devices for the washing and recovery of the precious metal contained in the gravel, sand, mud or earth, and redeposited in the same watershed from which it came shall not be classed as industrial waste.

The natural waters include lakes, bays, sounds, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, estuaries, marshes, inlets, straits, passages, canals, the Pacific Ocean, Gulf of Alaska, Bering Sea, and Arctic Ocean, within the state limits of the State of Alaska, and all other bodies of surface or underground water, natural or artificial, public or private, inland or coastal, fresh or salt, which are wholly or partially within or bordering the State or within its jurisdiction.

A law passed in 1968, AS 46.04.170, by the Legislature of the State of Alaska prohibits the discharge of petroleum, acid, coal or oil tar, lampblack, analine, asphalt, bitumen, or residues of products of petroleum to any waters of the state or to any place where the substances can reach waters of the state.

An Act providing a system for the appropriation and use of water and the establishment of a water resource board was enacted by the Legislature of the State of Alaska in 1966 (AS 46, Chapter 15, Article 1). This act deals with permits, determining uses and the administrating of the appropriation of water rights to the residents and industries of

Alaska. This area of water use indirectly affects the water quality considerations of the Inlet but will not be discussed further.

Local Laws. Ordinance No. 28-68 of the Greater Anchorage Area Borough establishes minimum design, construction, and installation standards for certain sewage disposal facilities and governs the handling and disposal of sewage wastes to prevent ground and surface water pollution. [64]

Alaska State Water Quality Standards

It is of interest to summarize briefly the procedures preceding the adoption of the State Standards.

Hearings were held in seven cities around the state on the proposed revisions to the State of Alaska Water Pollution Control Program and the State's Administrative Code, Title 7, Division 1, Chapter 2, Sanitation and Engineering. The hearings were properly advertised and conducted in accordance with the State's Administrative Code and an Information Bulletin was furnished to all interested persons both before and during the time of public hearings. The Information Bulletin, approximately 50 pages in length, was entitled "Proposed Standards for Water Pollution Control in the State of Alaska". Verbal and written testimony was received at the hearings. Also, written testimony was received through April 20, 1967, which was 10 days past the last hearing date. An Adjourned Hearing was held in Juneau on April 12, 1967, and also administrative sessions were held with various groups and individuals.

All reports, written and verbal, were reviewed and the following action was taken:

a. The proposed Water Quality Standards were adopted by the State of Alaska, Department of Health and Welfare. The Department of Health and Welfare is the State's Water Pollution Control Agency.

b. All municipalities with community sewage facilities, along interstate waters, primarily those with 500 population or larger, will provide sewage treatment by July, 1972.

c. Secondary treatment is required for all industrial waste and municipal waste unless acceptable engineering studies can show that the water quality standards can be met with primary treatment, which is the minimum acceptable treatment. No such exception to the secondary treatment requirement will be made unless an engineering plan is approved by the Department of

Health and Welfare and concurred in by the Federal Water Pollution Control Administration.

d. All interstate waters of the state were classified in accordance with the requirements of the State Statutes. The letter classification corresponds with those listed on the Table of Water Quality Standards.

Class	Description
A, B, C, D, E, F, G	All interstate waters
D, E	All coastal waters

All interstate waters may be reclassified at a future date when the need arises. Any person or group of people may petition the Commissioner of Health and Welfare and request a public hearing on the reclassification of any interstate state waters.

e. The Alaska Administrative Code, Title 7, Division 1, Chapter 2, was revised to update the existing standards with the new federal requirements and with modern technology. [199]

Waste Discharges to Cook Inlet

Direction action was taken by the State of Alaska at the time of submission of the Water Quality Standards to FWPCA for approval. The State Department of Health and Welfare is the State's Water Pollution Control Agency. The Department of Health and Welfare at the time required all municipalities with sewage systems along interstate waters and with populations of 500 or more to provide sewage treatment by 1962. At this time, secondary treatment for all municipal and industrial wastes will be required unless water quality standards can be met to the satisfaction of the Department of Health and Welfare and concurred in by FWPCA by primary treatment. Primary treatment will be the minimum acceptable treatment.

Domestic and Industrial Discharges. A table of municipalities, canneries, shellfish processors, and industries falling within the requirements of mandatory sewage treatment by 1972 is presented (Table III-7).

Ships. Discharges of oil from ships are prohibited by the Oil Pollution Act of 1924. Precautions are taken aboard ships for the containment of oil spills and drips. Ballast water, containing oil, from tanker ships is treated on shore at the Drift River marine loading facility.

TABLE III-7

CURRENT STATUS AND SCHEDULE FOR SEWAGE TREATMENT WORKS CONSTRUCTION IN ALASKA - JUNE 1967 -

Community or Industry	Preliminary Planning	Financing Being Arranged	Construction Planning	Under Construction	Completion Date
ANCHORAGE	X	X			1972
HOMER					1972
KENAI	X	X	X	X	1967
PALMER	X	X	X	X	1965
SELDOVIA	X	X	X	X	1969
A. Oil Industry					
Off Shore Facilities					
Shell - Partial Treatment					
Pan Am					1972
Mobil - Partial Treatment					1972
Union - Partial Treatment					1972
On Shore Facilities					
Standard Oil Refinery	X	X	X	X	1963
Shell Oil - Oil, Water Separator Facilities	X	X	X	X	1966
B. Petro Chemical					
Collier Carbon and Chemical Corp.	X	X	X	X	1968
C. Sea Food Processors (Located Outside of Communities to Provide Treatment by 1972)					
Location of Processor					
Beluga River					1972
Clam Gulch					1972
Cohoe					1972
Kalifonsky Beach					1972
Kasilof					1972
Kasitsna Bay					1972
Ninilchik					1972
Snug Harbor					1972
Major Federal Installations					
Elmendorf Air Force Base		- Part of Anchorage City Treatment Plans			1972
Ft. Richardson		- Part of Anchorage City Treatment Plans			1972
Wildwood Air Force Station					*

*Date to be set by Federal Government

State of Alaska Dept. of Health & Welfare [199]

RELATED ENGINEERING STUDIES

Introduction

Due to pressures of industrial and municipal expansion and development of the Cook Inlet area, many engineering studies have been conducted to acquire data for planning and construction. These studies include hydrologic and current studies as well as land and marine surveys. Earthquake damage, investigations on sea ice, water resources and sewage studies have also been subjects of engineering reports. The data included in the reports listed in the summary table (Table III-8) will be used as a basis for evaluation and background of the proposed data collection programs. The bibliography included within the appendices of this report will contain the full engineering report titles and pertinent information.

Evaluation of Reports

The reports listed were collected by the author during the preliminary work leading to the writing of this report and represent the major efforts by Federal, State and local agencies as well as studies conducted by the petroleum industry and consulting engineers. There are many studies and investigations that have not resulted in reports or data that could be obtained during the preliminary survey of existing information. However, these studies represent a very small portion of the work that has been carried out and documented in Table III-8.

TABLE III-8
SUMMARY OF ENGINEERING REPORTS RELATING TO COOK INLET

Title of Report	Author or Agency	Report Topic
The Alaska Earthquake, March 27, 1964, Investigation and Reconstruction [70]	U.S. Geologic Survey	Field Investigations and Reconstruction Efforts
Sea Ice Strength [152]	H. R. Peyton	Sea Ice
The Pollution of the Waters of Knik Arm [180]	State Dept. of Health & Welfare	Waste Disposal Practices
Waste Induced Oxygen Uptake of an Alaskan Estuary [144]	Institute of Water Resources	Biochemical Oxygen Demand
A Report on Water and Sewage Facilities at Public and Semi-Public Places [26]	Clark & Groff Engineers	Earthquake Damage
Water Study - Greater Anchorage Area, Alaska [10]	U.S. Geological Survey	Water resources in Anchorage Area
Greater Anchorage Area Sewage Study [184]	Tryck, Nyman & Hayes & Stevens & Thompson, Engrs.	Sewage System Design
Knik Arm Current Study [31]	Corps of Engineers	Current Study for Anchorage City Dock
Small Boat Harbors, Anchorage, Seldovia, Homer & Ninilchik	Corps of Engineers	Construction Reports
Foundation & Materials Investigation, Homer Spit, Alaska [35]	Corps of Engineers	Soils Investigation
Foundation and Materials Investigation Anchorage Small Boat Basin, Ship Creek Site [34]	Corps of Engineers	Soils Investigation

SUMMARY OF ENGINEERING REPORTS RELATING TO COOK INLET (cont.)

Title of Report	Author or Agency	Report Topic
Foundation and Materials Investigation, Anchorage Small Boat Basin, Chester Creek Site [33]	Corps of Engineers	Soils Investigation
Hydraulic Study for Causeway across Turnagain Arm (Personal Correspondence)	Armstrong & Assoc.	Hydraulic model
Tide and Soils Investigation - Turnagain Arm (Data Only)	Alaska Dept of Hyws.	Causeway planning
Report on Geophysical Investigation, Homer Spit, Alaska [62]	Corps of Engineers by Geo. Recon, Inc.	Reflection seismic survey

SUMMARY OF ENGINEERING REPORTS DEALING WITH COOK INLET

Report	Author	Client	Remarks
Oceanographic Investigation for a Wharf at Nikishka, Kenai Peninsula, Alaska [113]	Marine Advisors, Inc.	Standard Oil Co. of California	
Oceanographic Survey of Beluga-Moose Point Pipeline Route Across Cook Inlet, Alaska [114]	Marine Advisors, Inc.	Standard Oil Co. of California	
Oceanographic Investigation for an Oil Pipeline in the East Foreland Area of Cook Inlet, Alaska [111]	Marine Advisors, Inc.	Shell Oil Co.	
Survey of a Proposed Pipeline near Shell Oil Platform "A", Cook Inlet, Alaska [123]	Marine Advisors, Inc.	Shell Oil Co.	
An Oceanographic Survey for a Feasibility Study of a Highway Crossing of Turnagain Arm, Cook Inlet, Alaska [104]	Marine Advisors, Inc.	Tryck, Nyman, & Hayes	
A Study of the Oceanographic Conditions in the Anchorage Area Relevant to Sewage Outfall Planning. [115]	Marine Advisors, Inc.	Tryck, Nyman, & Hayes	
Certain Oceanographic Factors Relative to the City of Anchorage Waterfront Development Study	Marine Advisors, Inc.	Tryck, Nyman, & Hayes	
Oceanographic Investigations at Collier Wharf Site, Cook Inlet, Kenai Peninsula, Alaska [110]	Marine Advisors, Inc.	J. H. Pomeroy, Inc.	
Study of Wave Heights, Currents, and Their Resultant Forces in Trading Bay, Alaska [116]	Marine Advisors, Inc.	Atlantic-Richfield Co.	

SUMMARY OF ENGINEERING REPORTS DEALING WITH COOK INLET (cont.)

Report	Author	Client	Remarks
Oceanographic Investigations of the Phillips Petroleum Company's Marine Facility, Cook Inlet, Kenai Peninsula, Alaska [113]	Marine Advisors, Inc.	Bechtel Corp.	
Subbottom Survey of Phillips Petroleum Wharf Site, Kenai, Alaska [118]	Marine Advisors, Inc.	Bechtel Corp.	
Hydrographic and Oceanographic Survey for a Marine Terminal at Drift River, Cook Inlet, Alaska [106]	Marine Advisors, Inc.	Cook Inlet Pipeline Co.	
Supplementary Report on Ice Conditions for a Marine Terminal at Drift River, Cook Inlet, Alaska [119]	Marine Advisors, Inc.	Cook Inlet Pipeline Co.	
Ice Conditions for a Marine Terminal at Drift River, Cook Inlet, Alaska [108]	Marine Advisors, Inc.	Cook Inlet Pipeline Co.	
Currents Near the Mouth of Drift River, Cook Inlet, Alaska [105]	Marine Advisors, Inc.	Cook Inlet Pipeline Co.	
An Analysis of Oceanographic Factors Influencing Construction of Pier Facilities off Drift River, Cook Inlet, Alaska [103]	Marine Advisors, Inc.	Cook Inlet Pipeline Co.	
Hydrographic Survey in Trading Bay, Cook Inlet, Alaska [107]	Marine Advisors, Inc.	Union Oil Co.	
Survey of a Proposed Pipeline at Trading Bay, Cook Inlet, Alaska [124]	Marine Advisors, Inc.	Union Oil Co.	

SUMMARY OF ENGINEERING REPORTS DEALING WITH COOK INLET (cont.)

Report	Author	Client	Remarks
Survey of Proposed Pipeline at McArthur River, Cook Inlet, Alaska	Marine Advisors, Inc.	Union Oil Co.	
Oceanographic Conditions at Beshta Bay, Cook Inlet, Alaska [103]	Marine Advisors, Inc.	Humble Oil Co.	
Survey of a Proposed Pipeline at Granite Point, Cook Inlet, Alaska [120]	Marine Advisors, Inc.	Mobil Oil Corp.	
Survey of a Proposed Pipeline and Platform Site in Trading Bay, Cook Inlet, Alaska [122]	Marine Advisors, Inc.	Texaco, Inc.	
Survey of a Proposed Pipeline and Platform Site in Beluga-Moose Point Area, Cook Inlet, Alaska [121]	Marine Advisors, Inc.	Phillips Petroleum Co.	
Project and Index Maps [32]	Corps of Engineers		all Projects relating to rivers and harbors described
Water Resources Development [36]	Corps of Engineers		describes past, present, and future projects

III. PROPOSED DATA COLLECTION PROGRAMS

INTRODUCTION

In an environment conducive to development and industrialization, a wide variety of pollutants may be released to the estuary waters. With the hydrodynamic properties of the system adding to a possible concentrating effect, grave problems can arise. To make the best use of the estuarine waters and to avoid unbalancing the complex ecological system, knowledge is needed to predict and control the effect of man-made influences.

The purpose of this chapter is to (1) present and describe the relevant factors which must be considered in developing a complete baseline data collection program for acquiring environmental data on the waters of the Cook Inlet Estuary and (2) to delineate and discuss the individual data collection programs which must be conducted.

In proposing programs to acquire baseline environmental data, it is desirable to discuss the relevant factors which apply to an estuary in general. This chapter will describe the general data needs of a baseline characterization study. How an estuary system interacts temporally and spacially, and the general requirements in determining the frequency of investigations and sampling will be discussed.

The proposed data collection programs will deal with six general areas of investigation: hydrologic and hydrographic, geological oceanography, physical and chemical oceanography, biological oceanography, waste discharge inventories, and special studies. The proposed programs are designed for optimum implementation over a three-year period, although the total program can be extended over any time period with attendent decrease in efficiencies and increased capital outlays.

It should be noted that the Inter-Agency Technical Committee report [85] will be used extensively in presenting existing data collection programs and in locating sampling stations where possible.

At the present time the Cook Inlet drainage basin is the most intensively developed area in Alaska, although, by comparison to estuaries and drainage basins of the rest of the United States, it is sparsely settled and undeveloped. As Alaska grows and other areas develop, it is hoped the methodology and programs presented herein will be used as the basis for future investigations in tidal estuaries.

GENERAL REQUIREMENTS FOR DATA COLLECTION PROGRAMS

As a first step in the long-range plan for water resource management of the Cook Inlet estuary, the proposed data collection programs contained in this report will yield data for a baseline environmental description of the Inlet waters. The data collection programs, to be effective, must allow the acquisition of the parameters that will describe the present environment and changes brought about by the natural aging in the ecological system and the man-created changes through waste inputs.

Although some data on the Inlet water have been gathered for years, only in the past two to three years have attempts been made at determining the characteristics of the Cook Inlet estuary system. With increased industrial and population pressures, it is imperative that an environmental characterization be conducted in order that the water quality management objectives can be carried out with development of Cook Inlet, rather than waiting until problems occur which make abatement measures mandatory.

The data from the proposed programs are needed in order that (1) a description of the quality of the Inlet waters can be obtained; (2) the ecology of the Inlet environment can be characterized; (3) engineering judgments on waste outfall locations can be made with more confidence; (4) significant parameters can be developed with which to determine physical, biological, and chemical changes brought about by waste discharges; (5) a management framework can be developed to control and maintain the quality of the Inlet waters; and (6) significant and localized problems now occurring within the estuary can be resolved. The establishment of water quality standards for transparency, organic content of sediments, or other physical, chemical, or biological constituents would require that the background situation as it now exists be adequately described.

Estuary Characteristics

Estuaries are a transition stage of the joining of rivers, the ocean, and the adjacent land. The interaction of these three components must be understood and taken into account in attempting to determine the quality of the estuarine waters and the biota and sediments present within the estuarine environment. The variation and interaction of the various components within an estuary can be described both spatially and temporally. The following is a brief discussion of the factors controlling these variations.

Spatial Variation. The characteristics of the coastal topography, to a large extent, determine the spatial variation of the estuary water quality. Estuaries are classified by spatial complexity as either 1-, 2-, or 3-dimensional. A one-dimensional estuary has a flow characteristic in which the principal flow is unidirectional, parallel to the centerline, and has sufficient turbulence to cause vertical mixing. A two-dimensional estuary can be either (1) fully mixed vertically but have longitudinal and lateral motion, or (2) stratified vertically and flow constrained to the longitudinal axis. A three-dimensional estuary is stratified vertically and has flow characteristics both laterally and longitudinally. The Cook Inlet estuary can be classified as a two dimensional estuary with lateral and longitudinal flow with vertical mixing.

Temporal Variation. During certain periods of the year, Cook Inlet receives extremely large quantities of glacial melt water from streams of the Inlet shoreline, but the majority is concentrated at the head of the Inlet from the Susitna, Knik, and Matanuska Rivers. The tidal range in Cook Inlet rank second in the world, with the extreme range during spring and fall neap tides being approximately 40 feet in Anchorage. Both the tidal motion and the highly variable fresh water river inflows cause time-dependent variations in the sediment loads and water quality constituents of the Inlet waters. Sampling studies must consider the time-influencing factor in attempting to define the characteristics of the estuary waters accurately.

The net movement of quality constitutents toward the head or mouth of the estuary is affected by lunar and wind tides as well as river inflow. Thus estuaries can be classified not only in spatial dimensions but also as positive, negative, or neutral depending upon the direction of net movement of these constituents.

A positive estuary has a net movement of fresh water entering the upper end toward the mouth. Neutral estuaries have no net movement, thus any pollutant entering the estuary would either have to be withdrawn or have to increase in concentration. Negative estuaries have a net movement of seawater entering the mouth and progressing toward the head or landward. Normally an estuary is positive but can be classified by either or all three at different times throughout the year, or at different locations at any one point in time.

Frequency of Investigations

The frequency of sampling within the estuary is dependent upon the physical and economic limitations imposed upon the sampling programs and the statistical precision of acquiring valid data, based on the spatial and temporal variations discussed above.

The size, structure, and climatological conditions of Cook Inlet make sampling programs difficult at best. The upper Inlet is subject to great tidal ranges and the exposure of large mud banks at low tides in Knik and Turnagain Arms make boat sampling at low tide impossible. High sediment loads impose mechanical problems upon the propulsion machinery of the sampling craft. During winter months, the ice floes in the upper Inlet reach a maximum of 42 inches in thickness. These constantly moving ice floes extend through the Forelands area into the lower Inlet. Navigation in the upper Inlet is impossible in the winter ice months to all but the larger freighters bringing supplies to Anchorage. Thus, to carry out sampling activities at all, rugged and sophisticated equipment, necessarily expensive, must be used.

Conditions in the lower Inlet are much the same as conditions in the open ocean. The large expanses of water can cause wave conditions to become extreme. Biologically, the lower Inlet is more productive, and studies of population dynamics and plankton, which require sampling over large areas during several seasons, can be accomplished without major problems.

The restrictions imposed by the above conditions will result in different types of sampling activities occurring at various locations in the Inlet at different times of the year. The specific activities, locations, and scheduling will be discussed in more detail in the chapter on implementation of the data collection programs. Ideally, the sampling activities should detect the variation of parameters with time and space. The frequency of sampling varies with the type of parameter. For example, tidal currents and tide stages are on a semi-diurnal cycle and determining the characteristics of these requires continuous sampling through a single day. Biological conditions change more slowly and maximum variations are found on a monthly or seasonal basis.

Precision of sampling techniques affect the frequency and number of samples taken. The number of samples required to establish confidence intervals on parameters in question must be evaluated on the basis of site measurements.

PROPOSED DATA COLLECTION PROGRAMS

The purpose of this section is to describe the important characteristics of the individual data collection programs presented in the following sections of this chapter. The relationship of some Inter-Agency data collection stations to the proposed program data collection stations will be included. The organization and scheduling of the proposed data collection programs, will be discussed.

Programs

Data collection will be facilitated by dividing the data requirements into six sections: hydrographic and hydrologic; geologic, with emphasis on sediment characteristics and transport; physical and chemical characteristics of the estuarine waters; biological inventories and ecological interactions; waste discharge inventories; and special studies dealing with localized and immediate problems that have occurred and are now present in the estuarine water due to waste discharges and industrial effects.

It is recognized that the various sections noted above interact and are dependent on other influences, for example: the biological specie and the ecological system are dependent upon the tides, currents (hydrographic), nutrients and solar radiation (chemical and physical), and to some extent, the suspended sediments and bottom deposits (geologic). These important interactions are discussed within the specific sections on data requirements, but the data required to study the effects and impact of the various influences are best collected within separate programs due to the types of sampling and analyses required.

Inter-Agency Program Data Collection Stations

Various agencies and institutions have ongoing data collection programs in Cook Inlet; in some instances these programs are to be expanded and new programs instituted. These ongoing and new programs are presented on tables, maps, and graphs contained in the Inter-Agency Technical Committee for Alaska report, "Alaska - Ten Year Comprehensive Plan for Climatological and Hydrographic Data." For the most part these various programs are on shore and incorporation of these programs for the Cook Inlet area will augment and expand the scope of the proposed data collection programs contained in this report. The existing and proposed data collection stations for programs of the Inter-Agency Committee report are excerpted from the Committee report maps and are inserted within the specific chapters to which the data collection stations apply. In monitoring the quality and quantity of river inputs to Cook Inlet, the Inter-Agency report had proposed monitoring stations

on the important rivers but the schedule for implementing these monitoring stations could not be determined. Therefore these desired stations were included in the proposed data collection stations of this report.

Proposed Data Collection Stations

Due to the types of data to be collected and the physical and climatic restrictions imposed by the Cook Inlet environment, the data collection stations are separated into three categories. The same station locations in each category are carried throughout each of the data location programs, although some programs will not use all or any of the stations in each category. The consistency of location is needed to reduce scheduling and costs of visiting each station to sample. The types of stations are terrestrial, intertidal, and offshore, and are shown on the large map at the end of this report.

Terrestrial. The numbers attached to each station location will be used to develop a master station log which will detail the station location, types of samples to be collected at each station, and the frequency of sampling throughout the three years of the data collection program. The major importance of terrestrial stations is to develop a biological inventory of land based flora and fauna, although river monitoring stations are also included within this category. Details on types of samples collected at these terrestrial stations will be included within the specification data collection programs.

Intertidal. Climatic restrictions will reduce the sampling in the upper Inlet during winter months. The major emphasis on intertidal sampling is to study the biota although sediments and physical and chemical sampling will be conducted. Shore tide stations are also included within the intertidal stations.

Offshore. The basic grid of 44 stations are the minimum number needed to characterize the offshore environment of Cook Inlet. Circulation patterns, sediment characteristics and transport, plankton and physical and chemical determinations will be conducted at these offshore stations. It is anticipated that first year studies will not utilize the total grid but will use a selected number of stations. The number will be determined by the climatic conditions and the type of data to be collected. Winter sampling will be restricted to the lower Inlet because of the large quantities of ice prevalent during the winter. The criteria for determining the location and sampling schedule was that the offshore stations are conducive to sampling by a large oceanographic research vessel.

Sampling Methods and Techniques

In the appendix, a-propriate references for the various mehtods and procedures are presented. These references should be consulted before attempting field studies.

Program Organization and Time Schedule

Two proposed data collection programs are presented in the following cahpters, 1) an optimum, four phase coordinated program and 2) an alternate program with smaller scale studies completed as the need for the specific data becomes apparent.

Optimum Program. This program is designed to be conducted in four phases with four years being the minimum length of time needed to complete the study. The length of the study can be extended to meet budgetary limitations.

Four years are felt to be the minimum to obtain valid data on the Inlet, to develop the management structure for evaluating and guiding the individual data collection programs, and to develop the necessary data storage, analysis and management capabilities to handle the large amount of data resulting from the collection programs effectively.

The first phase will be devoted to hiring personnel, developing detailed sampling schedules, developing a basic hydraulic simulation model, and establishing a temporary data bank to store, analyze, and retrieve data from the sampling cruises.

The second phase of the proposed program will be devoted to a pilot study to test and determine the feasibility of the sampling network and the frequency of sampling. During the second phase, simulation models of circulation patterns and chemical budgets within the Inlet will be started, based on available data. The second year data will corrobrate the accuracy of the models. A limited number of sampling stations will be used. Also, biological inventories will be made. Tables and maps within the individual sections following on the proposed data collection programs will detail the second phase activities.

The third and fourth phases will use the expanded or total proposed station grid and will be modified based on the pilot program results.

Alternate Program. The data collection program proposed as an alternate to the above described "optimum program" lists specific smaller scale data collection activities in order of the priority of data needs. No time scale is presented. The type of data to be collected under this alternate program remains the same only the means by which it is collected and the order of collection is changed. The priorities of the data collection activities are based upon population growth and anticipated construction of new facilities near or in Cook Inlet. This program is described fully in Chapter VI "Program Implementation."

HYDROGRAPHIC AND HYDROLOGIC DATA COLLECTION PROGRAMS

Introduction

Hydrologic and hydrographic data is essential when consideration is given to the water quality of Cook Inlet or to the possibility of engineering and construction of projects in the Inlet and on the adjacent shores.

This chapter will describe the types of hydrologic and hydrographic data that are relevant in evaluating the present status of the Inlet waters. The objectives and benefits of obtaining the data will be mentioned and the existing data collection programs and studies that have been conducted in the past will be reviewed. The data collection stations of the various climatological and hydrological data collection programs presently underway or planned by the Inter-Agency Technical Committee will be discussed within this chapter. Finally, the proposed data collection programs are presented and described. Since the Inter-Agency Report emphasizes land-based sampling stations, the proposed data collection programs will augment and complement the Inter-Agency programs and result in a more definitive characterization of the Cook Inlet estuary system.

Types of Data

Before attempting to discuss the needs and requirements of hydrologic and hydrographic data collection programs, it is necessary to describe what hydrographic and hydrologic data are. The following outline is a breakdown of the various categories of data. A discussion after the outline will describe each type of data.

Hydrographic Data

- Water Volumes
- Surface Areas
- Cross-Sectional Areas
- Hydraulic Depths
- Tides
  - Mean Tidal Elevations
  - Tidal Ranges
  - General Wave Characteristics
  - Tidal Prisms
- Currents
  - Surface Currents
  - Subsurface Currents
  - Coriolis Forces

Hydrologic Data

- Climatological Data
  - Precipitation
  - Evaporation
  - Evapotranspiration
  - Surface Radiant Energy
  - Winds
  - Ice
- Sources and Sinks
  - Surface Water
    - Stream Runoff
    - Delta Outflow
    - Storm Water
    - Waste Water
    - Marshland Flooding
  - Ground Water
    - Description of Aquifers
    - Subsurface Exchange

Hydrographic Data. Water volumes are a measurement of the total amount of water within the estuary. This volume changes due to tides and within large estuaries such as Cook Inlet where the tide stage or elevation of surface of the water varies with location, large errors will result if amplitudal time lags are not considered. Surface areas are the area of the inlet water surface. These are usually computed during different tide stages, and in shallow estuaries, can vary considerably in magnitude. The tideland area is assumed to be the difference between surface areas at mean high tide (MHW) and mean low low tide (MLLW). The corss sectional area is the area of a vertical section of the area of the estuary at a specific location in the inlet, the section being perpendicular to the center line of the estuary from mouth to head. The hydraulic depth is the average depth of the estuary at that section and is obtained by dividing the cross sectional area by the surface width of the inlet at that point.

Tides are caused by gravitational effects of the sun and moon. Certain terms pertaining to tidal characteristics bear explanation. Tidal prisms are defined as the volume of water lying between high and low tides. Since in Cook Inlet high tide and low tides do not occur everywhere at the same time, time lags and tidal waves are present within the estuary. The computed volume of water (tidal prism) will be in error if the tidal wave is not considered. Tidal prisms in this case are drived from sectional volume relationships and the total tidal volume is the summation of the section volumes.

Currents are caused by tides and the rotational effects of the earth acting on the water mass. These rotational effects are due to the basic law of conservation of momentum and are called coriolis effects or forces.

Surface currents are caused by winds, tidal effects, and surface runoff from rivers, while subsurface currents, often at variance with surface currents, can be caused by tides and coriolis forces.

Hydrologic Data. Climatological data includes precipitation as rain and snow, evaporation, evapotranspiration, and surface radiant energy. Within the estuary water boundary, surface radiant energy is of interest in that the amount of energy falling on the surface of the water has an effect on the growth of phytoplankton and other marine plants. Winds affect surface currents and movement of floating material.

Sources and sinks are the amount of water discharged to the estuary and the amount of water removed from the estuary due to various factors. Sources include stream runoff, storm water, waste discharges, and underground inflow from aquifers. Sinks include municipal water withdrawals, and inflow to underground aquifers. Subsurface exchange determines the relationship between the water flow and exchange between the estuary and underground aquifers.

Data Needs and Requirements

At the present time very little is known about the hydrographic and hydrologic conditions of Cook Inlet, and with increased pressures on water quality control, knowledge of the above conditions will have many uses. It is most important to develop a dynamic estuarine description of Cook Inlet which will incorporate parameters relating physical, chemical, and biological aspects. In describing the inlet conditions at present, spacial and temporal variations within the environment, either brought about by natural causes or man induced development, can be documented.

Direct benefits of hydrological and hydrographic studies are: (1) submarine waste outfalls can be located more effectively and with the least harmful effect on the biota of the waters; (2) offshore construction of drilling platforms and other facilities can be achieved more easily; (3) petroleum oil spills can be monitored and direction of travel can be predicted; (4) locations, direction of travel, and dispersal of pollutants can be predicted; (5) recreation potential of Cook Inlet shores can be developed more easily; (6) sea ice now hindering winter transportation can be monitored and shipping made more efficient; and (7) the transport of sediments, now filling the upper inlet at a rapid rate, can be studied.

The state of knowledge of the hydrologic and hydrographic aspects of the Inlet requires that priorities of importance are placed upon the types of data needed. Due to physical and financial limitations of acquiring hydrologic and hydrographic data, a sequence of data collection programs should be established with primary data to be collected first and,

as data collection techniques are improved and data output from initial programs are evaluated, more refined studies can be made to broaden and refine the dynamic estuary model.

Of primary importance is the definition of the general circulation patterns within the inlet. Primary data required for establishing and circulation patterns in the upper and lower inlet are winds, tides, and currents. Salinity and diffusion characteristics are important parameters but it is felt that these refinements can be made at a point later in the data collection programs. Salinities and other chemical constituents should be monitored initially but not intensively. These constituents will be discussed in the chapter on physical and chemical oceanography data collection programs.

After general circulation patterns within the inlet are established, diffusion characteristics and the effects of fresh and saline intermixing on a seasonal basis should be developed. Salinity concentrations approach oceanic concentrations in Knik and Turnagain Arms in winter months due to greatly decreased glacier fed river flow. Summer conditions cause great quantities of fresh water to enter the inlet headwaters and both chemical makeup and circulation patterns are greatly affected. Surface water runoff studies require more intensive climatological investigations.

In addition to data collection programs based around sampling and monitoring stations in Cook Inlet a computer model developed to simulate general circulation patterns within the inlet is necessary. Preliminary data gathered at the tide, current and weather stations in the past few years would allow a simple model to be developed. This model would detect weak points in the proposed data collection station network and also yield a greater understanding of the circulation processes within the Inlet. This model could be developed coincidentally with a primary data station network.

Based on preliminary circulation studies and a computer simulation model, more elaborate data collection programs can be developed to describe finally a full dynamic estuary system which will require the full scope of the data needs presented at the beginning of this section.

Review of Existing Data and Studies

Historically, the various hydrologic data of rainfall, snowfall, and wind velocities have been collected by the U.S. Weather Bureau, and stream flow discharges and water quality information have been collected by the U.S. Geological Survey. Weather information has been obtained at various points on the boundaries of Cook Inlet where either airport observers or volunteer observers have been available. Stream flow has been

monitored for many streams which are available to the existing surface modes of transportation and which appear to possess important characteristics as indicators of the general hydrology of a given area. Thus, the hydrologic data thus far collected has not been collected with regard to its direct bearing on Cook Inlet. Unfortunately, most of the north and west shores of the Inlet have been relatively inaccessible, so very little stream flow and weather information has been collected in those areas.

Most available information regarding the hydrographic data in Cook Inlet has been obtained by U.S. Coast and Geodetic Survey and by the Institute of Marine Science of the University of Alaska. The bathymetry work performed by the U.S. Coast and Geodetic Survey has provided a set of charts for the Cook Inlet area which is probably adequate for water quality studies except in areas of the upper Inlet where continuous channel changes make frequent updating necessary. The Institute of Marine Science work has been associated primarily with the upper segment of Cook Inlet, but has not included Turnagain Arm or Knik Arm. In addition to hydrographic surveys, the U.S. Coast and Geodetic Survey has monitored tidal amplitudes at various locations along the shores for many years.

Table No. IV-1 contains a listing of reports bearing specific data on Cook Inlet. The reports listed by number contain data and information relevant to the study area but are too numerous to list by name. A number of publications and texts contain material of interest to persons desiring to become more familiar with hydrologic and hydrographic problems and approaches and are listed in the table by number. These numbers are keyed to the bibliography where complete information on the references are available.

In addition to the data collection programs operated by the various governmental agencies and the specific studies referred to by title in the table mentioned above, many surveys and small scale engineering problems as well as oceanographic investigations for design and construction of offshore oil drilling platforms have acquired valuable information about currents and the topography of the Inlet floor. The investigations by Marine Advisors, Inc. on the oceanography of Cook Inlet for the various oil companies contain valuable data on very specific locations in the Inlet. The area covered by the survey and the currents measured were for a specific purpose and the data does not lend itself to being easily incorporated into an environmental description. Precise bathemetric charts have been made of portions of the inlet where drilling platforms are located. Pipeline routes on the inlet floor have been mapped and the currents and topography of these areas have been intensively investigated.

The Alaska Department of Highways has investigated proposed crossings of Turnagain and Knik Arms and information on tides, currents, and bottom characteristics within the areas of these crossings has been

TABLE IV-1

REPORTS AND PUBLICATIONS DEALING WITH HYDROGRAPHIC AND HYDROLOGIC DATA COLLECTION PROGRAM

Reports and/or Publications	Agency or Author	Remarks
Reports Containing Specific Data on Cook Inlet		
Clay-Inorganic and Organic-Inorganic Associations in Aquatic Environments, Part II [22]	Institute of Marine Science	An article contained in this report contains hydrologic data on sediments, sea ice, and currents.
Oceanography of Cook Inlet [164]	Institute of Marine Science	Contains oceanographic data with reference to the Collier Carbon effluent outfall.
Water Study-Greater Anchorage Area, Alaska [10]	U.S. Geological Survey-City of Anchorage & Greater Anchorage Area Borough	Open file report on hydrology of Anchorage area.
Greater Anchorage Area Sewage Study [184]	Tryck, Nyman & Hayes and Stephens and Thompson, Consulting Egrs.	Contains oceanographic data for design of sewer outfall for city of Anchorage.
Effects of the March, 1964 Alaska Earthquake on the Hydrology of South-Central Alaska [192]	U.S. Geological Survey	Shows effects on waters in streams, groundwaters, and Cook Inlet due to earthquake.
Seismic Seiches from the March 1964 Alaska Earthquake [131]	U.S. Geologic Survey	An interpretation of the continental distribution of seiches from the earthquake.
Sea Ice Strength [152]	H. R. Peyton	Contains stress-strain data on sea ice data on offshore facilities and design.

Reports Containing General Data on Cook Inlet

[25, 31, 37, 57, 70, 75, 85, 101, 105, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 154, 160, 180, 185, 186, 191]

Publications and Texts Dealing with Subject Area

[38, 56, 68, 78, 88, 99, 151, 153, 157, 162, 177, 189, 193, 210, 211]

assembled for evaluation and design.

Much of the above information is in the form of unpublished reports, charts, and tables that are available but in forms that require extensive analysis before meaningful information can be achieved.

On Figure. IV-1, all of the existing climate stations shown record maximum and minimum temperatures and precipitation data. Four are fire weather sites which in addition to temperatures and precipitation also monitor dry bulb, wet bulb, and dewpoint temperatures. Two stations measure wind velocities, nine measure pressure, dry bulb and dewpoint temperatures, winds, sky cover, cloud heights, visibility and weather. One station measures snow density, four stations measure evaporation and two measure solar radiation.

Figure IV-2 shows proposed climate stations. Fourteen of the sixteen stations shown are to record precipitation, maximum and minimum temperatures. Four stations will record wind data, one station will report evaporation and solar radiation.

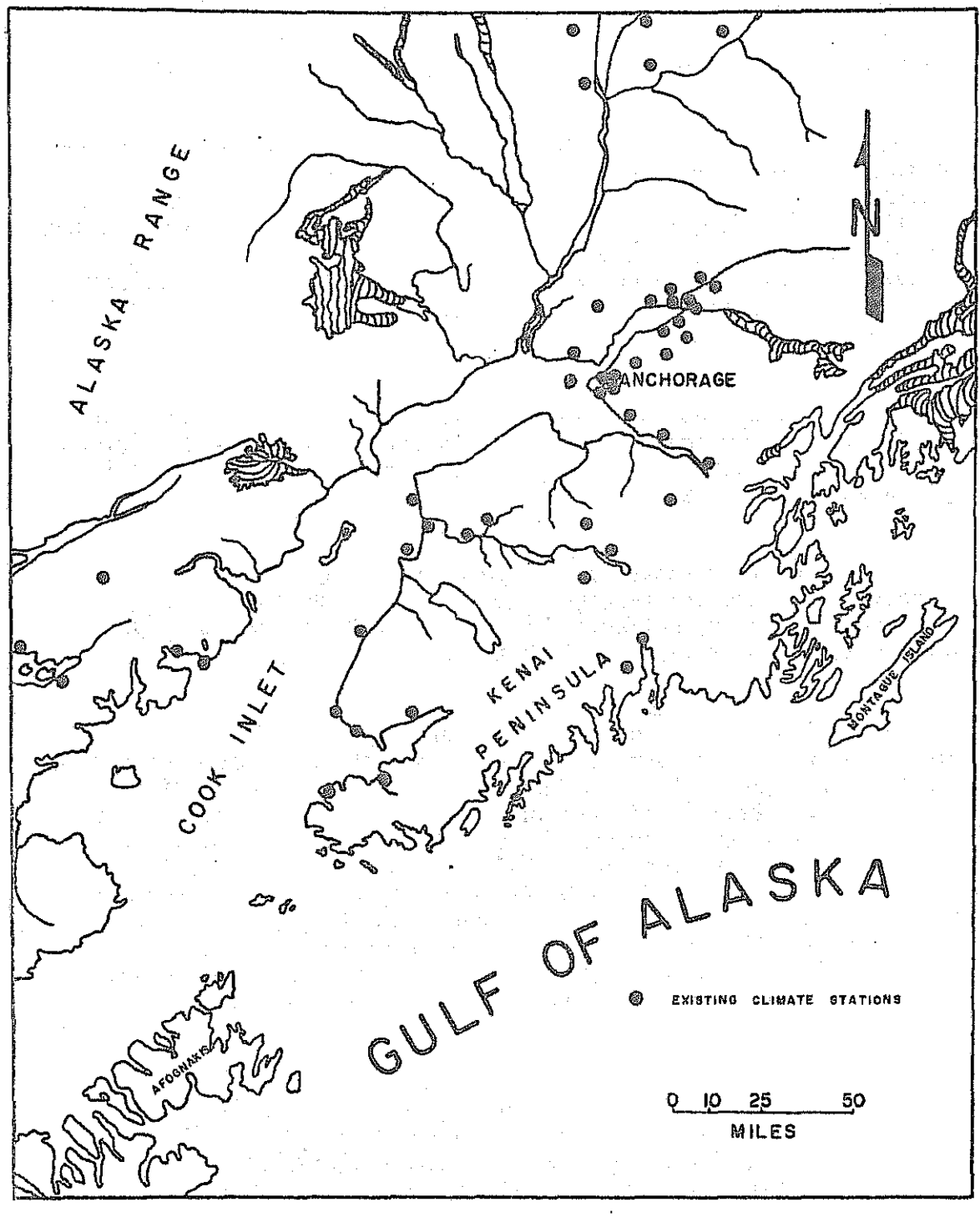
Figure No. IV-3 shows streamflow partial record stations. These stations include crest-stage gages and low flow measuring sites to augment records collected at regular data or areal stations. The surface water and water quality stations are shown on Figure No. IV-4, 5.

Information on the physical and hydraulic characteristics of aquifers is used to solve problems associated with development of ground water supplies. Figure IV-5. shows the ground water area studies, areas where precise or detailed information on certain areas is needed. Such information as water use, springs, determination of amount of water available and proper well spacing are included within the areal studies. Observation wells are used for determination of water level fluctuations in aquifers from natural and man-made changes in the amount of ground water in storage. The solution to many ground water problems begins with accurate data on water level fluctuations. Figure. IV-6 shows locations of observation wells used in the study of water level fluctuations.

Snow-surveys provide basic information used primarily in forecasting runoff from watersheds. Types of data gathered at these survey stations include snow depth, snow density, water equivalent, and general weather and environmental conditions at the time of observation. Figure IV-.7 shows the existing and proposed snow stations.

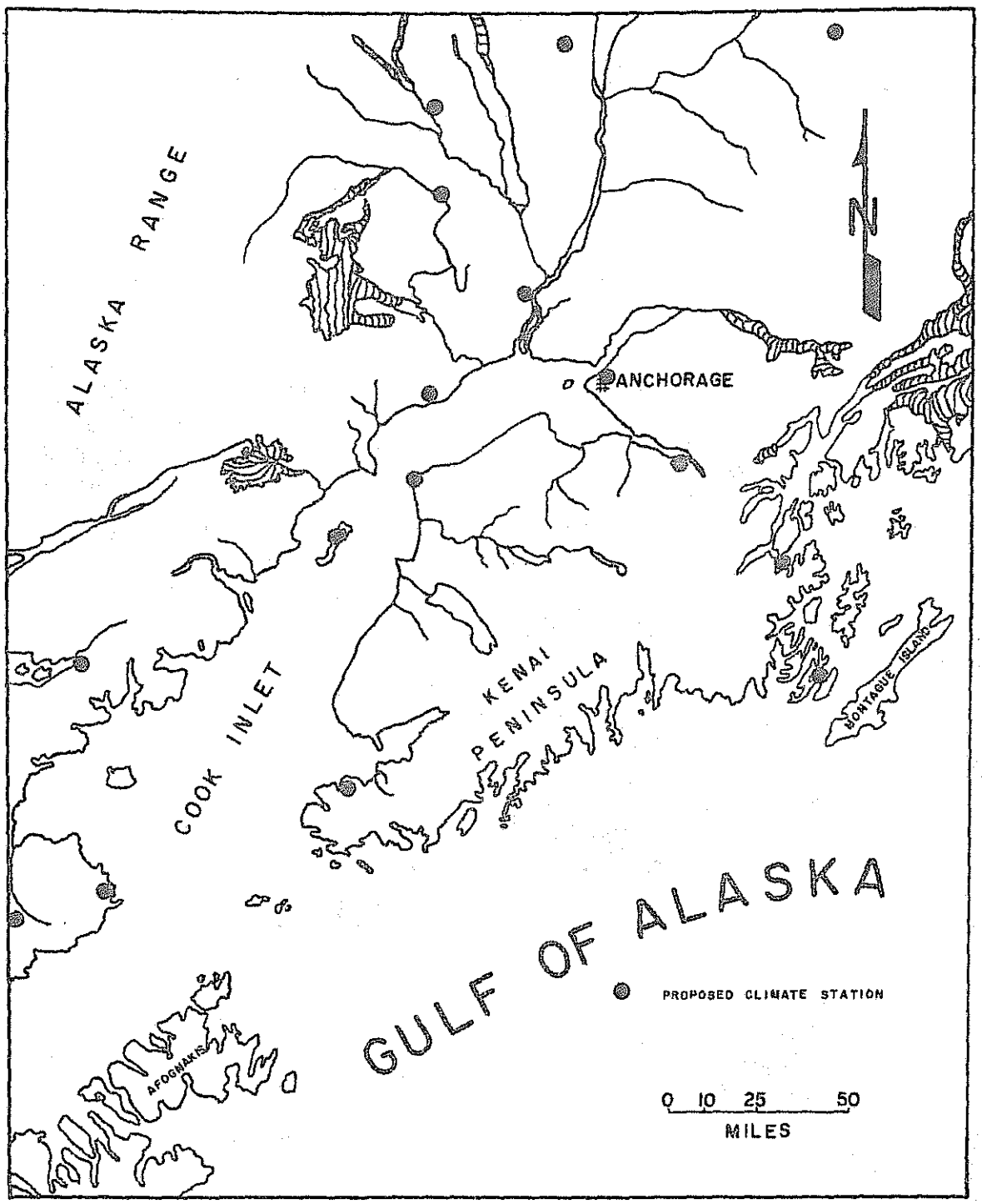
Hydrologically, glaciers are natural reservoirs which store water for long periods of time in the solid state. The goal of

FIGURE IV-1



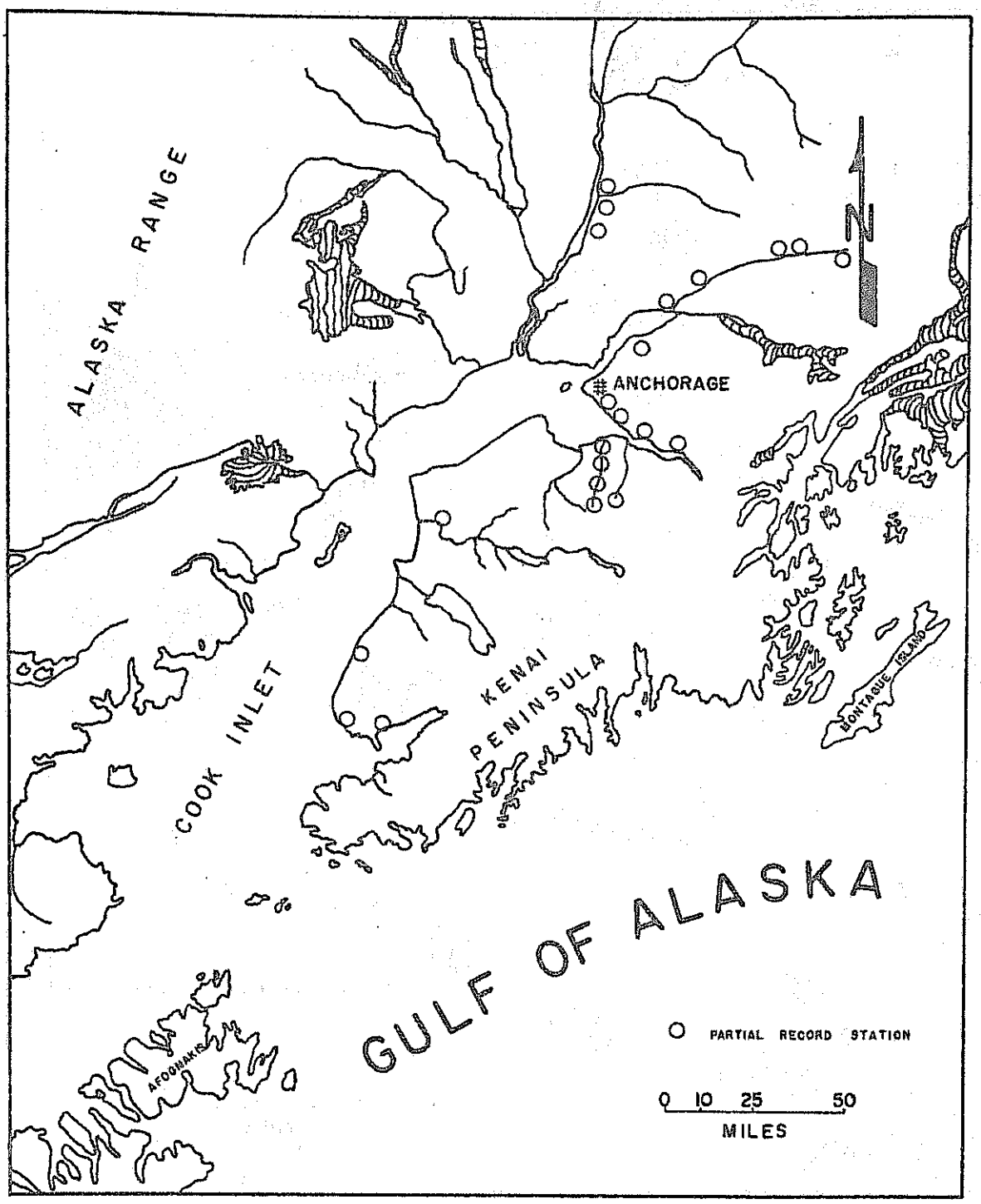
EXISTING CLIMATE STATIONS
U.S. Weather Bureau [85]

FIGURE IV-2



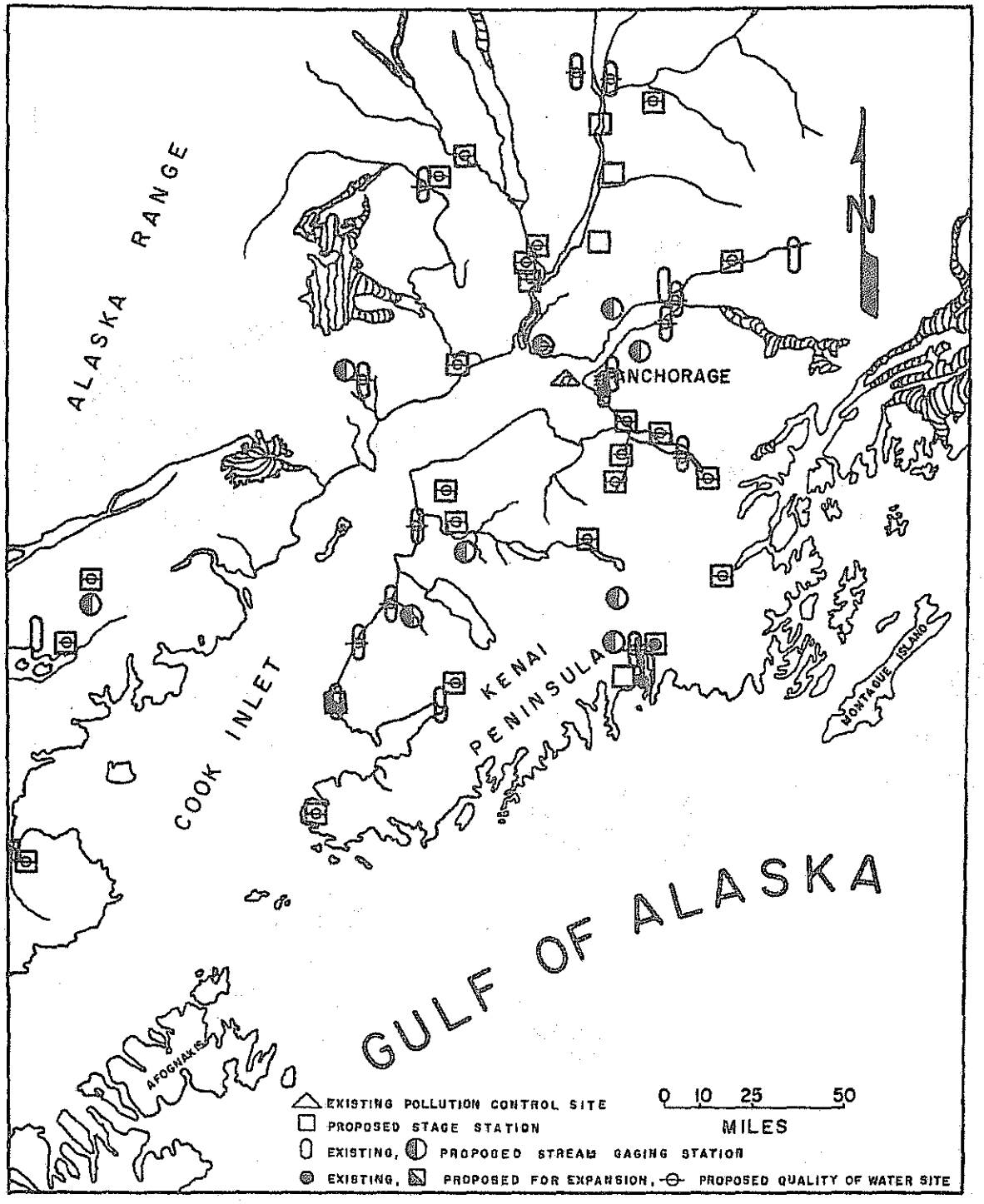
PROPOSED CLIMATE STATIONS [85]

FIGURE IV-3



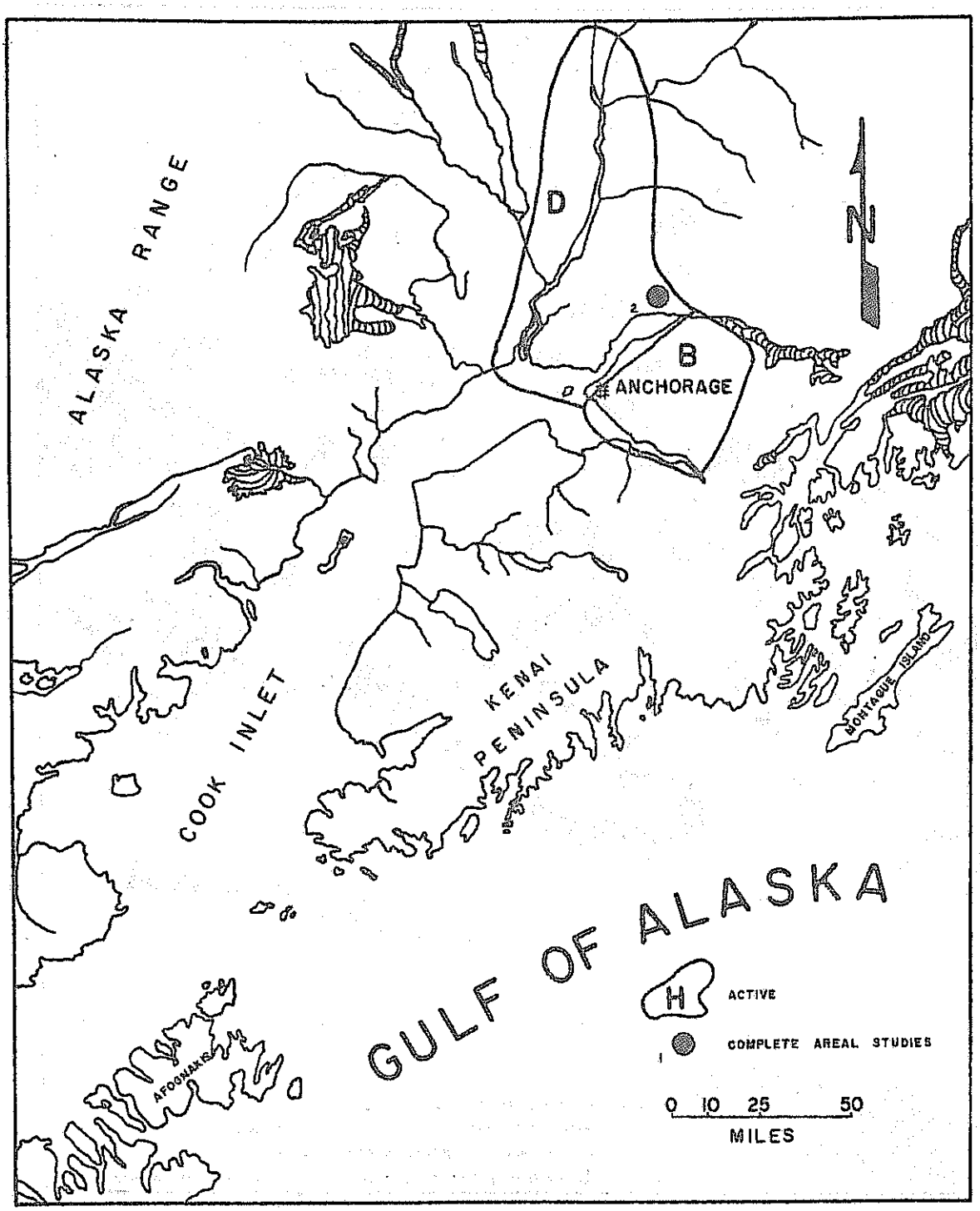
EXISTING STREAMFLOW PARTIAL RECORD STATIONS [85]

FIGURE IV-4



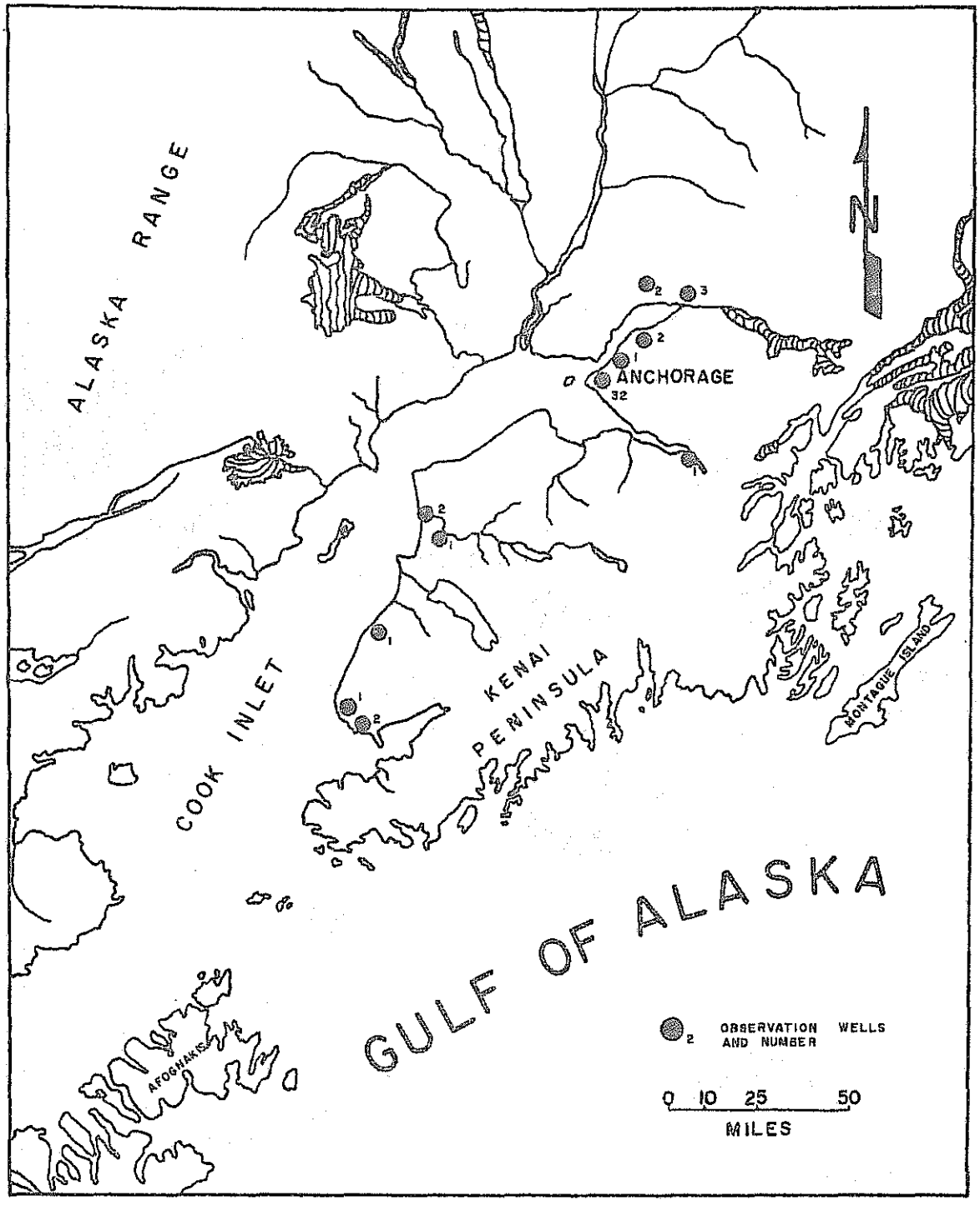
SURFACE WATER AND WATER QUALITY PROGRAM [85]

FIGURE IV-5



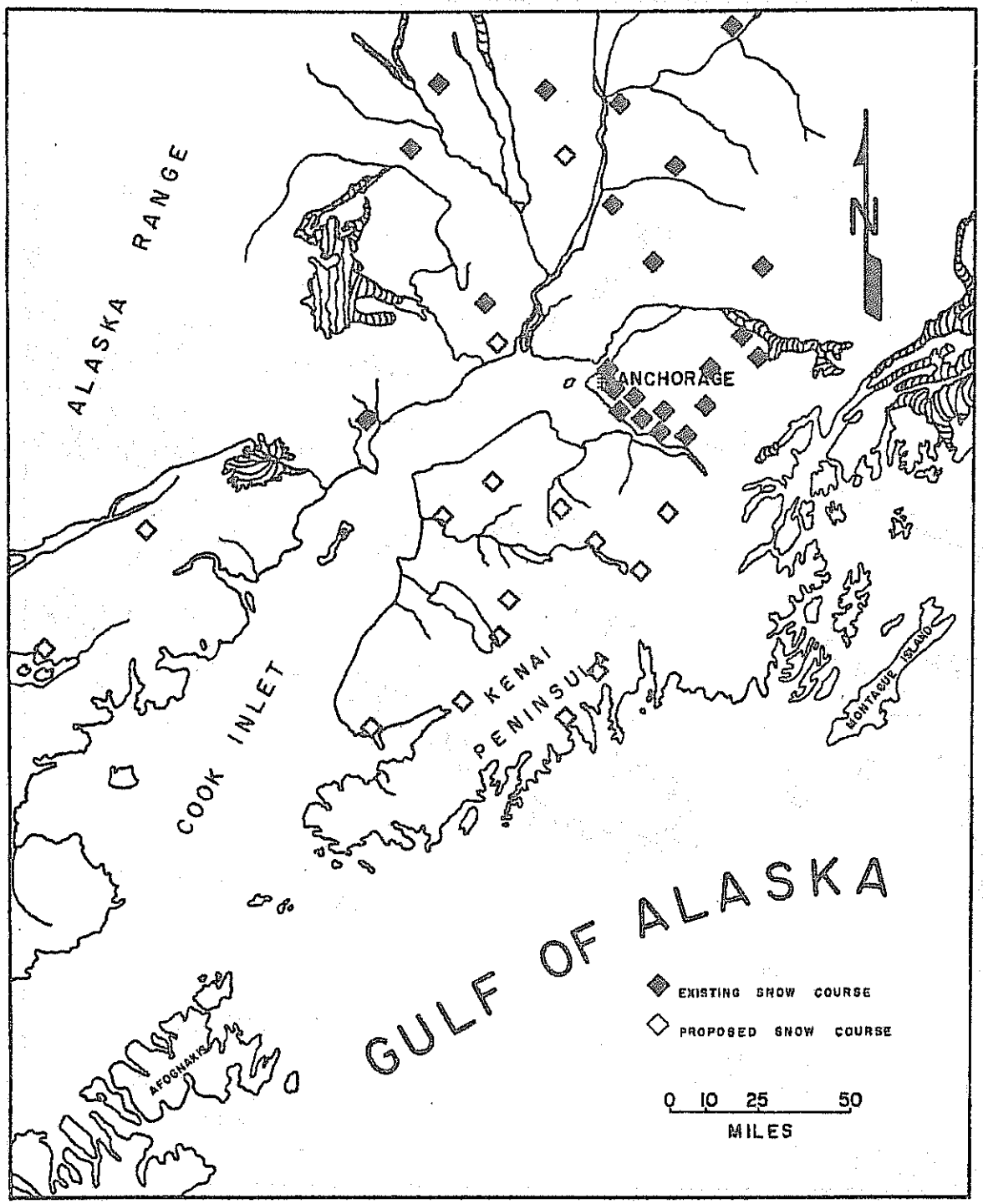
GROUND WATER PROGRAM [85]

FIGURE IV-6



GROUND WATER OBSERVATION WELLS [85]

FIGURE IV-7



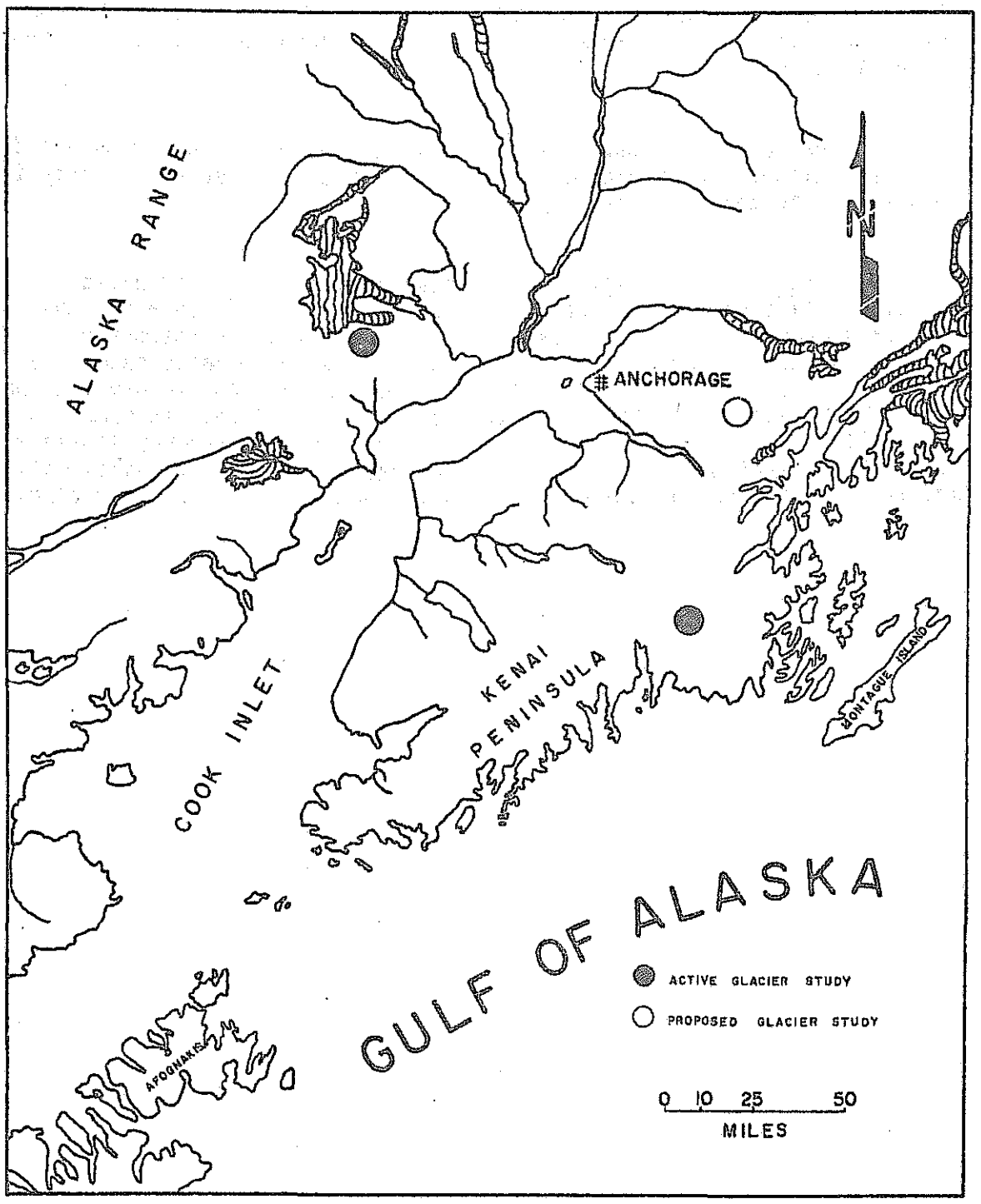
PROPOSED AND EXISTING SNOW COURSE MONITORING AREAS [85]

hydrologically oriented glacier studies is to measure fluctuations in the amount of water stored and to determine the effect of these fluctuations on the regime of related surface and groundwater systems. Figure No. IV-8 indicates locations of existing and proposed glacial monitoring activities.

A network of primary tide and surface sea-water temperature and density stations are maintained by the U.S. Coast and Geodetic Survey in Cook Inlet and are shown on Figure IV-9.

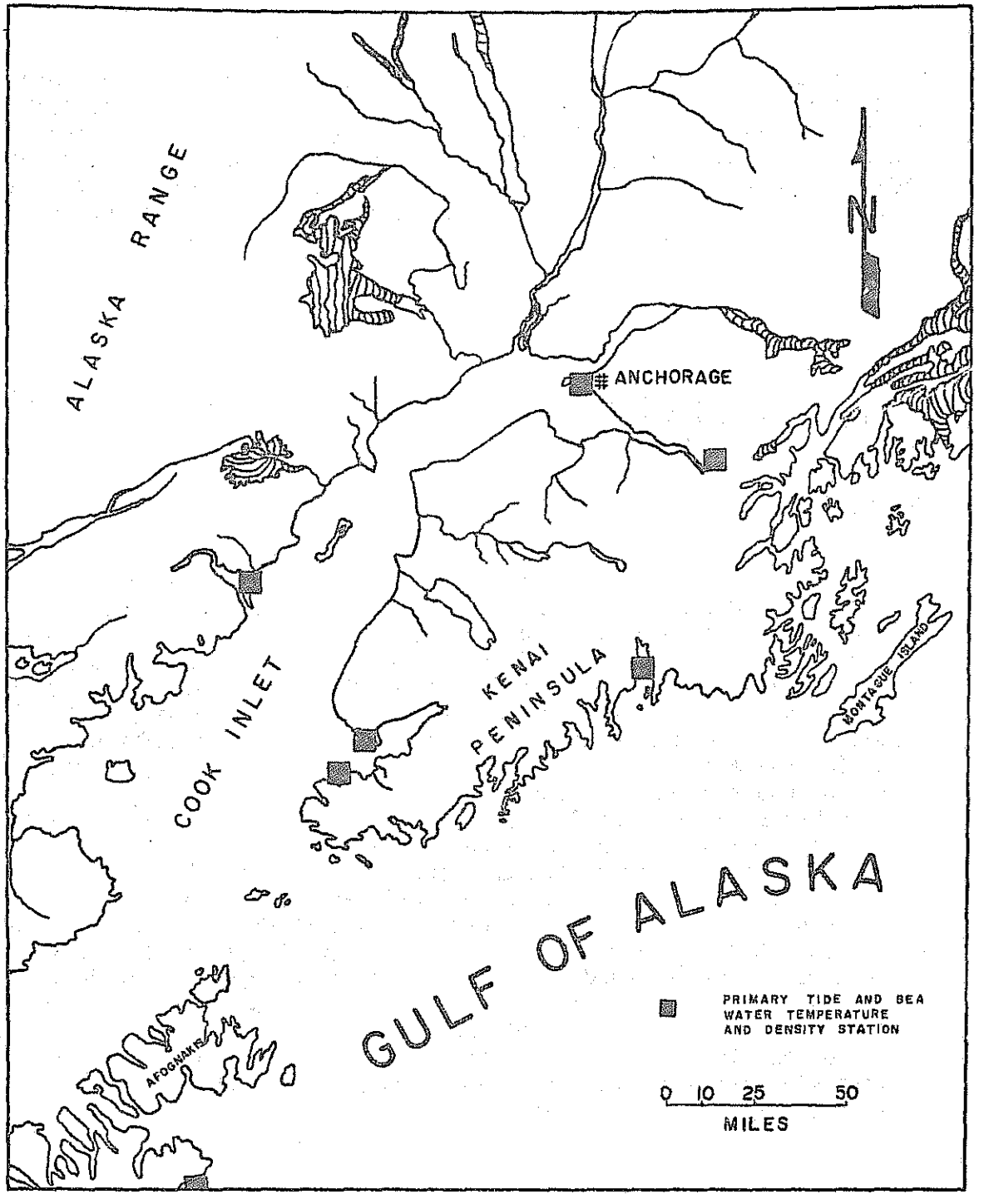
Summary and Evaluation. The climatologic and land based hydrologic data collection programs seem to be quite adequate for the initial stages of developing data collection programs to characterize the environment of the waters of Cook Inlet. Major emphasis should be placed on acquiring tide and current information in order to develop the circulation patterns of the Inlet waters. As initial data is acquired and evaluated, it seems possible that some of the Inter-Agency Ten-Year Plan data collection stations might be changed to yield more valid data, but at this time no recommendations can be made for relocating stations.

FIGURE IV-8



ACTIVE AND EXISTING GLACIER MONITORING AREAS [85]

FIGURE IV -9



TIDE MONITORING STATIONS [85]

Proposed Data Collection Programs

The hydrology of Cook Inlet is to a great extent dependent upon the hydrology and climate of the Cook Inlet drainage basin. The Inter-Agency report discussed in the previous chapters has a well established program in this area. The emphasis of the proposed data collection program for hydrology and hydrography will supplement the Inter-Agency programs in general and the major emphasis will be placed upon describing the tides and current patterns within the Inlet waters. The second year, third year and fourth year studies will be described below.

First Phase

The first phase will be devoted to organization and scheduling of manpower and sampling cruises.

Second Phase

The establishment of a major data network should be preceded by a simulation model of circulation in the Inlet. The second phase of the hydrologic and hydrographic program should be devoted to the development of such a model. The data stations of the Inter-Agency programs provide sufficient data to establish a basic simulation model, but a few stations should be established during the second phase to provide data that will corroborate the results of the basic model. The new and existing stations of the Inter-Agency programs, and the types of data to be collected during the second phase proposed program are presented in Table No. IV-2. The table is keyed to maps showing the locations of the data collection stations. It is proposed that three new climate stations and two streamflow gaging stations be established, as shown on Figure No. IV-10. Three tide stations should be established on the west side of the Inlet, as shown on Figure No. IV-11. During the second phase, three new tidal amplitude and current stations within the Inlet, shown on Figure No. IV-11, will be monitored. The ice conditions prevalent in the upper Inlet from October through May will restrict offshore boat work to four stations in the lower Inlet. The stations of the summer and winter programs are shown on Figures No. IV-10 and IV-11. Current stations are to be monitored continuously over a diurnal cycle and each station should be visited at least bimonthly during the year.

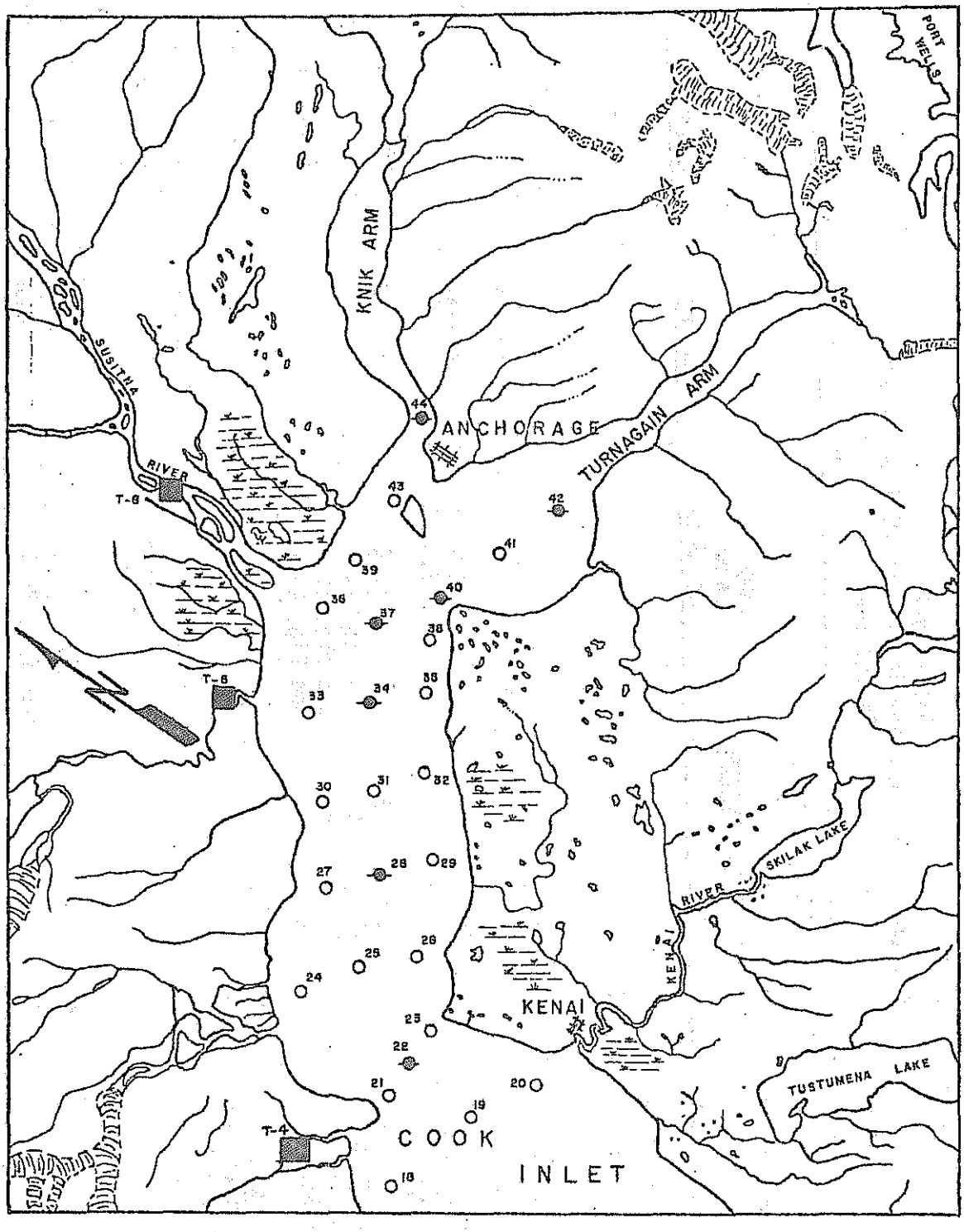
Third Phase

During the third phase the simulation model will be modified by the results of the initial efforts and the data collected. Salinity and diffusion parameters will be incorporated into the scope of the model

TABLE IV-2
HYDROLOGIC AND HYDROGRAPHIC DATA COLLECTION PROGRAMS
(Second Year)

Measurement Activity	Stations New	Stations Inter E	Stations Inter P	Stations Total	Sampling Station Loc. & No.	Frequency	Remarks
Develop Mathematical Estuary Simulation Model							
Terrestrial Zone							
Climate	3	49	14	63	See Figs. IV-1,IV-2,IV-10	Weekly	
Streamflow							
Gaging	2	20	9	31	See Figs. IV-4 & IV-10	Continuous	
Crest Monitoring		21	28	49	See Figs. IV-3 & IV-10		
Groundwater							Area basis
Aquifer Studies		2		2	See Fig. IV-5		
Observation Wells		47		47	See Fig. IV-6		
Snow Surveys		25	17	42	See Fig. IV-7		Snowcourses
Glacier Studies		3	1	4	See Fig. IV-8		
Intertidal Zone							
Tide, Temperature and Density	3	4		7	See Figs. IV-9, IV-10, & IV-11	Continuous	New Stations-Tide stage only
Off-shore							
Current							
Summer	6			6	See Fig. IV-10, IV-11	Bi-monthly	
Winter	4			4	See Fig. IV-11	Bi-monthly	

FIGURE IV-10

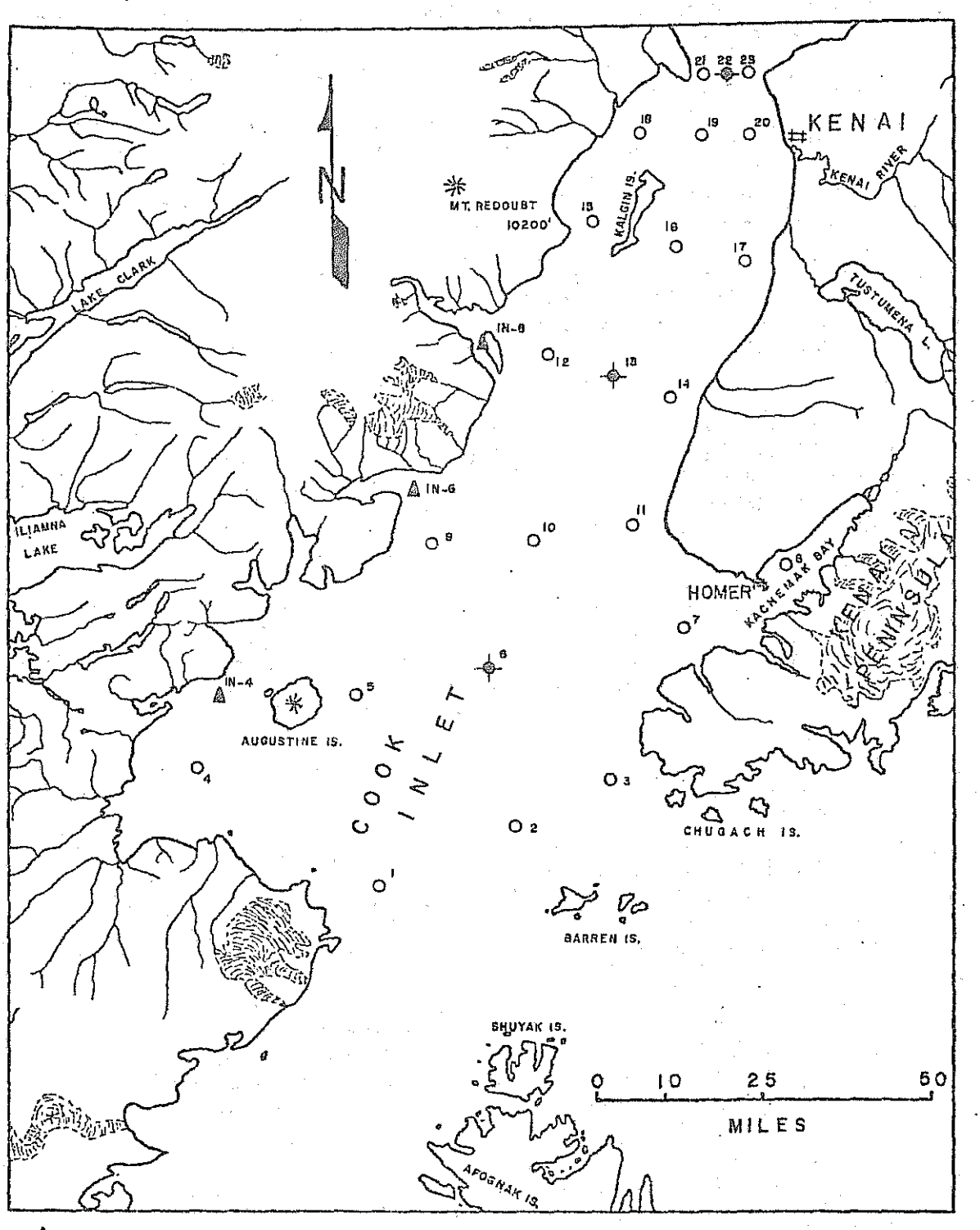


○ PROPOSED AND ◎ FIRST SAMPLING YEAR CURRENT STATION -◎- SUMMER

▩ FIRST SAMPLING YEAR STREAMFLOW STATION

0 5 10 20
MILES

LOCATION OF PROPOSED HYDROGRAPHIC AND HYDROLOGIC DATA COLLECTION STATIONS, UPPER COOK INLET



▲ FIRST SAMPLING YEAR TIDE STATION

○ PROPOSED AND ◎ FIRST SAMPLING YEAR CURRENT STATION, —◎— SUMMER ⊕ WINTER

LOCATION OF PROPOSED HYDROGRAPHIC AND HYDROLOGIC DATA COLLECTION STATIONS, LOWER COOK INLET

framework. It is not possible at this time to anticipate the network of sampling and monitoring stations that will be used, but the selection of the stations will be dictated by the results of the second-phase studies. Additional sampling of the general circulation will probably be necessary in order that the integrity of the simulation model may be determined and enhanced. It will certainly be necessary to determine water volume and surface areas at various phases of the tide in order to assist in determining mass transport, particularly through the two critical areas of the mouth of the Inlet and through the Forelands area. It is felt that the U.S. Coast and Geodetic Survey charts are, as they presently exist, probably adequate for water quality management purposes in those areas south of the Forelands but may be somewhat lacking in the areas farther north. Consequently, new hydrographic surveys should be made periodically, particularly in the northern end of the Inlet.

It does not appear that the fresh water contribution to the Inlet is great as compared to the total water mass encompassed by the Inlet. However, since only weak salinity gradients can result in extremely high diffusion rates, it is desirable to better delimit the rates at which fresh water is contributed to Cook Inlet during various times of the year.

An expanded weather data collection network, particularly for gathering precipitation and wind information, should be established along both shores of Cook Inlet and Calgon Island. The Inter-Agency program has proposed some of the required stations.

Presently oil exploration is creating offshore structures in rather widely separated areas of the Inlet. These structures should be utilized to obtain quite valuable information. This is particularly important with regard to wind data, as winds are apparently responsible for appreciable perturbations in the Inlet's tides. In addition, wind data from new, offshore locations can probably be correlated with long-standing stations in order to hindcast wave situations which existed during historically significant storms.

It is doubtful that groundwater movement into or out of the Inlet need be measured at this time as far as general circulation or pollution of the Inlet is concerned. There are, of course, localized areas where this may be important, but only as it affects isolated, onshore areas.

Sea ice in the Inlet will probably have little effect on the overall water quality picture; however, it should be mentioned that studies of the frequency, occurrence, and nature of the sea ice in the Inlet should be made. Studies on sea ice will be described in the physical and chemical and also the geological proposed data collection programs.

Fourth Phase

The fourth phase will allow an expanded monitoring network to be used to justify the results of the first two phases of monitoring and simulation model development. Model studies will include the addition of simulation of sediment transport. The data collection activities for this simulation work will be described within the proposed geologic data collection activities. It is anticipated that the major emphasis will be placed on intensive tide and current monitoring with difficusion characteristics in the upper Inlet being defined. The practical application of diffusion studies will allow determination of the effect of discharge of Anchorage sewage.

GEOLOGICAL DATA COLLECTION PROGRAMS

Introduction

An estuary maintains an intricate balance between the sediment supply, the sediment transport and the hydrodynamic regime. During its life cycle the estuary is continually modified and finally becomes extinct. Man-made structures and changes in chemistry of water due to addition of pollutants adversely affect the estuarine regime and may result in the acceleration of filling of the estuary. Before an effort is made to evaluate the effects of man's activity in Cook Inlet, it is pertinent to understand and define the natural changes which result from its normal evolution.

This chapter will describe the types of data and the requirements for determination of sediment sources and the processes responsible for sediment transport and deposition. Existing data and studies will be reviewed and data collection programs will be proposed to facilitate acquiring a baseline description of the geological and sediment conditions of the Inlet as it now exists.

Data Needs and Requirements

The sedimentation processes existing in Cook Inlet are not directly basic properties of the Inlet waters, but are a result of the complex hydrodynamic and biological interactions that form the estuarine environment. The sediments themselves are composed of organic and inorganic particulate matter. The importance of the need to determine the sediment processes is due to the fact that these particulate substances are transported and deposited in such a manner that beneficial uses of the Inlet are restricted to varying degrees and also since the estuarine environment is in a dynamic state of change, the estuary will eventually become extinct. Table No. IV-3, lists the factors which interact and cause movement and deposition of these particulate substances. Any investigation of sedimentation processes within the inlet must consider the biological and hydrodynamic state of the regime in order to fully describe the processes now existing. It should be noted that although hydrological, hydrographic, chemical and physical properties, biological conditions, and waste discharges all interact and are listed in the table as factors influencing sediment transport and deposition, many of these factors will be determined as parts of data collection programs described in other sections of this report, and the major emphasis of the data collection programs proposed within this chapter will be directed toward characterizing the types and quantities of the sediments within the Inlet regime.

Geologically, an estuary is a transitional feature in the process of coastal accretion and is estimated to last for a few thousand years.

TABLE IV-3

DATA NEEDS FOR DETERMINATION OF SEDIMENTATION PROCESSES

- Properties of Estuarine Sediments
  - Physical Composition
    - Texture
    - Sand Content
    - Silt Content
    - Clay Content
    - Gravel Content
    - Median Diameter
    - Sorting
  - Chemical Properties
    - Organic Content
    - Inorganic Content
    - Calcium Carbonate
    - Nitrogen
- Sources of Sediments
  - Terrestrial
  - Oceanic
  - Biologic
  - Waste Discharges
- Interaction of Sediments and Water Flows
  - Transport
    - Rivers
    - Tides and Currents
    - Diffusion Characteristics
    - Sea Ice
    - Density Gradients
  - Deposition
    - Chemical Flocculation
    - Gravity
    - Velocity Gradients
    - Wave Action
    - Flow of Water-Mud Mixtures
    - Turbulence

Extinction generally results from advancing of river deltas and bordering depositional flats. Estuaries such as Cook Inlet, on unconsolidated sediments, change very rapidly. Broad marshes occupy vast flat surfaces that have been built up by deposition to about the level of high tide. Advancing deltas at the mouths of the Susitna, Beluga, Matanuska and Knik Rivers add to these depositional flats. The high concentrations of suspended sediments in upper Cook Inlet are derived mainly from glacial origins and are comprised of sediments of a large range of sizes. The turbulence in Cook Inlet is sufficient to entrain clay, silt and sand, but it is not known what proportion of suspended sediment is carried out to sea. The sediments within the waters of Cook Inlet are variable and continually modified by continental sediments brought into the inlet waters by surface flow, by marine sediments which are carried by flood tides, and by topographical considerations resulting from the alternate flooding and exposure of tide flats. The dispersal of these sediments is associated with the mixing of fresh and ocean waters and through hydrodynamical considerations such as turbulence, currents and density gradients due to sediment concentrations, bed load flow, and salinity variations. Depositional characteristics are often due to chemical flocculation and velocity gradients.

The southern shores of Cook Inlet are composed of Mesozoic volcanic, igneous, and metamorphic rocks, and erosion of these shoreline cliffs adds to the stratified material and glacial till, derived from the upper Inlet. Another factor contributing to transport and deposition of sediments is sea ice which forms on tidal flats in upper Cook Inlet in winter. Ice forms on tidal flats during low tide and is lifted and stacked during high tides at which time sediments are removed from the flats and encased within the ice floes. It is thought that a sizeable portion of the sediments of larger grain size are transported into the lower inlet through melting and breaking up of these ice floes as they pass through the Forelands area.

The data collection programs proposed within this chapter will determine the nature, rate, depositional patterns of sediments, and the changes in the above parameters during the evolutionary cycle of the Cook Inlet Estuary and also will provide a background against which the effects of waste inputs to Cook Inlet can be measured. To accomplish these objectives, the lithology of the sediments needs to be compared to delineate their respective sources. Data on the elemental distribution and composition should reflect the constancy of the chemical-mineralogical content of each size fraction and the chemical maturity of the sediments. Data on the distribution of heavy minerals should be obtained and evaluated to verify the lithological and chemical results.

The rates and depositional patterns of the Inlet should be studied and data on the thicknesses and location of stratigraphic horizons in the bottom of the Inlet will reveal relative rates of deposition

and ages of the sediments.

Textural maturity is the most important key to the physical nature of the environment of deposition since it provides a descriptive scale which indicates the effectiveness of the environment in winnowing, sorting, and abrading the detritus in the Inlet. Statistical data will reflect the mode of transportation and environment of deposition. A range, average station-to-station difference, and a moving average is needed for each of three textural parameters. The moving average calculations measured in the direction of dominant current eliminate the effects of local and anomalous parameter variations. Combined with areal distribution of sediments of different size fractions, the textured features of detritus can elucidate the mode of transportation and depositional environment.

Relatively small regional variations in texture and composition of sediments in Cook Inlet can indicate the past, and present direction of sediment sources, major transporting agents and the gross environmental characteristics.

Review of Existing Data and Studies

Very little work has been done within the waters of Cook Inlet to characterize the environment of suspended sediments and bottom deposits. Table No. IV-4 lists reports that apply specifically to sediment studies within the Inlet and also to geological studies conducted within the Cook Inlet drainage basin.

Oceanographic studies have been conducted in Cook Inlet during the summers of 1966, 67 and 68. Data for the 1966 and 1967 cruises have been evaluated and published. The 1968 cruise report is not yet available. Sediment study stations in both 1966 and 1967 cruises were concentrated in the upper Inlet with six of 38 sampling stations located south of the Forelands area in 1966 and eleven of 32 stations south of the Forelands in 1967. The two reports prepared by the Institute of Marine Science contain descriptions of the studies, and data are presented as tables and charts. These reports are listed in Table IV-4 and also in the bibliography.

The U.S. Geological Survey quality-of-water investigations are concerned with chemical and physical characteristics of the surface and ground waters. Records of chemical analysis, suspended sediment and temperatures of surface waters are published in Quality of Surface Waters of Alaska. The most recent publication is the 1961-63 volume. Sediment

TABLE IV-4

REPORTS AND PUBLICATIONS DEALING WITH GEOLOGICAL OCEANOGRAPHIC DATA COLLECTION PROGRAM

Reports and/or Publications	Agency or Author	Remarks
Reports Containing Specific Data on Cook Inlet		
Quality of Surface Waters of Alaska, 1961-63, Water Supply Paper 1953 [101]	U.S. Geologic Survey	Contains data on sediments entering Cook Inlet.
Oceanography of Cook Inlet [164]	Institute of Marine Science	Data on currents, suspended sediments, bottom sediments and geology of Cook Inlet Basin.
Clay-Organic and Organic-Inorganic Associations in Aquatic Environments Part II [22]	Institute of Marine Science	Article in this report discusses sediments and sedimentation in Cook Inlet
Reports and Publications Containing General Information on Study Area		
[37, 46, 49, 58, 62, 76, 85, 118, 152, 180, 191]		
Publications and Texts Dealing with Subject Area		
[6, 68, 87, 89, 99, 157, 169, 174, 177, 209, 210, 212]		

samples were taken during 1961-1963 at the following locations in the Cook Inlet basin: Ninilchik River at Ninilchik, Snow River near Lawing, Placer River at Portage, Twenty-mile River at Portage, Susitna River at Oenall, near Cantwell, and at Gold Creek. River discharge rates, suspended sediment concentrations, and estimated discharge of sediment in tons are presented. A majority of the sediments in Cook Inlet are derived from three rivers, the Susitna, Matanuska, and the Knik. The Matanuska and Knik Rivers are well monitored at the mouth and it appears that the sediment data is sufficient. The Susitna River has been monitored only periodically and emphasis should be placed on obtaining sediment sampling on a daily basis near the mouth of the river during the summer months. Since all three rivers are glacially fed, winter flow values are very low, subsequently sediment loads are also reduced during winter months.

The U. S. Coast and Geodetic Survey during bathymetry studies determines the general characteristics of the Inlet bottom and intertidal zones for incorporation on their navigational charts. The information gathered is of some qualitative value but overall contributes little to the characterization of the sediment environment of Cook Inlet.

Proposed Data Collection Programs

First Phase. This phase will be devoted to scheduling cruises, hiring manpower, developing a data storage system, and organization of the second, third, and fourth phase activities.

Second Phase. The primary emphasis during the second phase pilot program will be placed on delineating the sources of sediments in Cook Inlet. Sediment samples from the major rivers discharging to Cook Inlet and from the periphery of the estuary will be taken. The Knik and Matanuska Rivers are now being monitored under U.S. Geologic Survey programs; however, the Susitna and Beluga Rivers will have sediment and chemical parameters monitored at the stream gaging stations established under the proposed hydrological program. Sediment concentrations and characteristics will be determined. Shore line sediment sources from ice, shore cliffs, and shoals and mudbanks will be sampled to determine the character and amounts of sediments removed or deposited. Measurements of the amounts of sediment transported by winter ice will be subject to climatic conditions and development of a quantitative sampling method. Shoreline cliffs should be surveyed biannually to determine gross quantities of material removed. It is proposed that several representative locations within the Inlet be chosen and a method developed during the pilot study to make quantitative measurements.

Bottom and suspended sediments samples from the Inlet will be collected in a station pattern designed to provide a uniform density of coverage of samples from all parts of the Inlet.

Cores from different locations will be obtained from the Inlet using a two-inch OD piston corer. The cores will be extruded and split diametrically and vertical changes in the lithology described. The cuts from cores at depths showing significant differences in lithologic parameters will be taken for further analysis.

The laboratory work will include determination of major elements (Si, Al, Mg, Ca, K, Na, Sr, Mn, Fe and P) in various size fractions of the sediments from the river to the mouth of the Inlet. Sediment samples obtained will be fractionated into 1/4 phi intervals by wet sieving and pipette analysis. The core samples will be collected only once during the course of investigation and will be taken at 12 stations on the centerline of the Inlet from the head to the mouth.

The Offshore stations will be monitored during the summer and winter; however, winter sampling will be restricted to the lower Inlet. The sediment transport characteristics of the Inlet will be briefly monitored during the second phase and suspended sediment samples will be taken twice during the summer ice-free months and once during the winter sampling. Bottom sediments will be sampled once during the summer and once during the winter sampling cruises. The second phase activities are summarized in Table No. IV-5 and the sampling locations for river monitoring, shoreline sampling, and offshore summer and winter boat stations are located on Figures IV-12, IV-13.

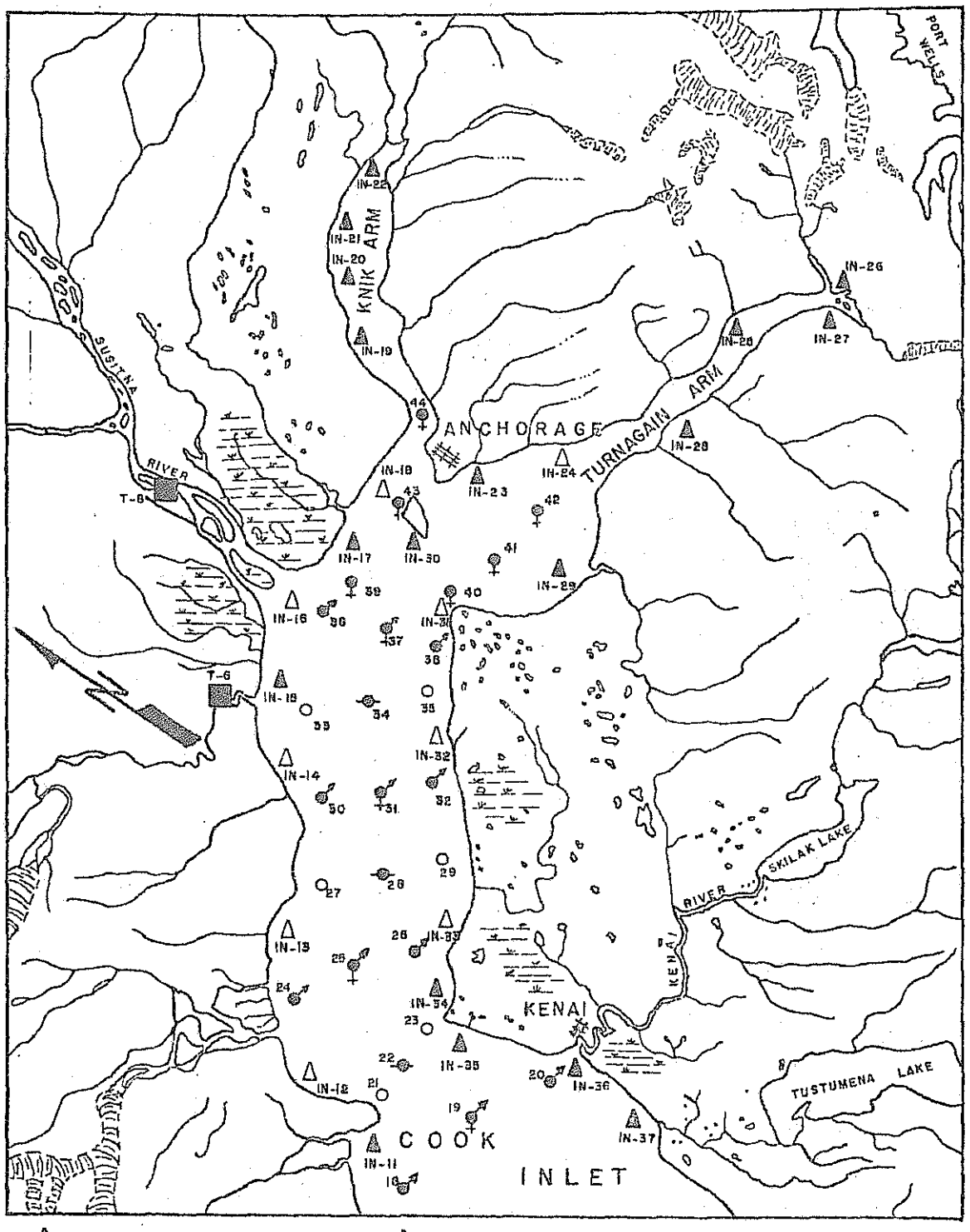
Third Phase. Based on results of the second phase pilot study, the sampling stations will be relocated if needed and the number of stations sampled will be increased. The emphasis of the third phase will be to determine the rate and depositional pattern of the Inlet sediments. In addition, heavy minerals from individual fractions of sediments will be separated and identified. By the end of the third phase, sufficient data will have been collected to be used in the development of the simulation model which in the third phase will incorporate sediment transport characteristics into the general circulation and salinity simulation.

Fourth Phase. Based on the simulation model results and the information and experience gained from the previous two years' sampling, the characteristics of the depositional environment, and the changes in the sedimentary environment due to industrialization and the natural evolutionary cycles of Cook Inlet can be developed. Sampling stations will be monitored as necessary, and laboratory analyses and data analyses will be completed.

TABLE IV-5
GEOLOGIC DATA COLLECTION PROGRAM
(Second Phase)

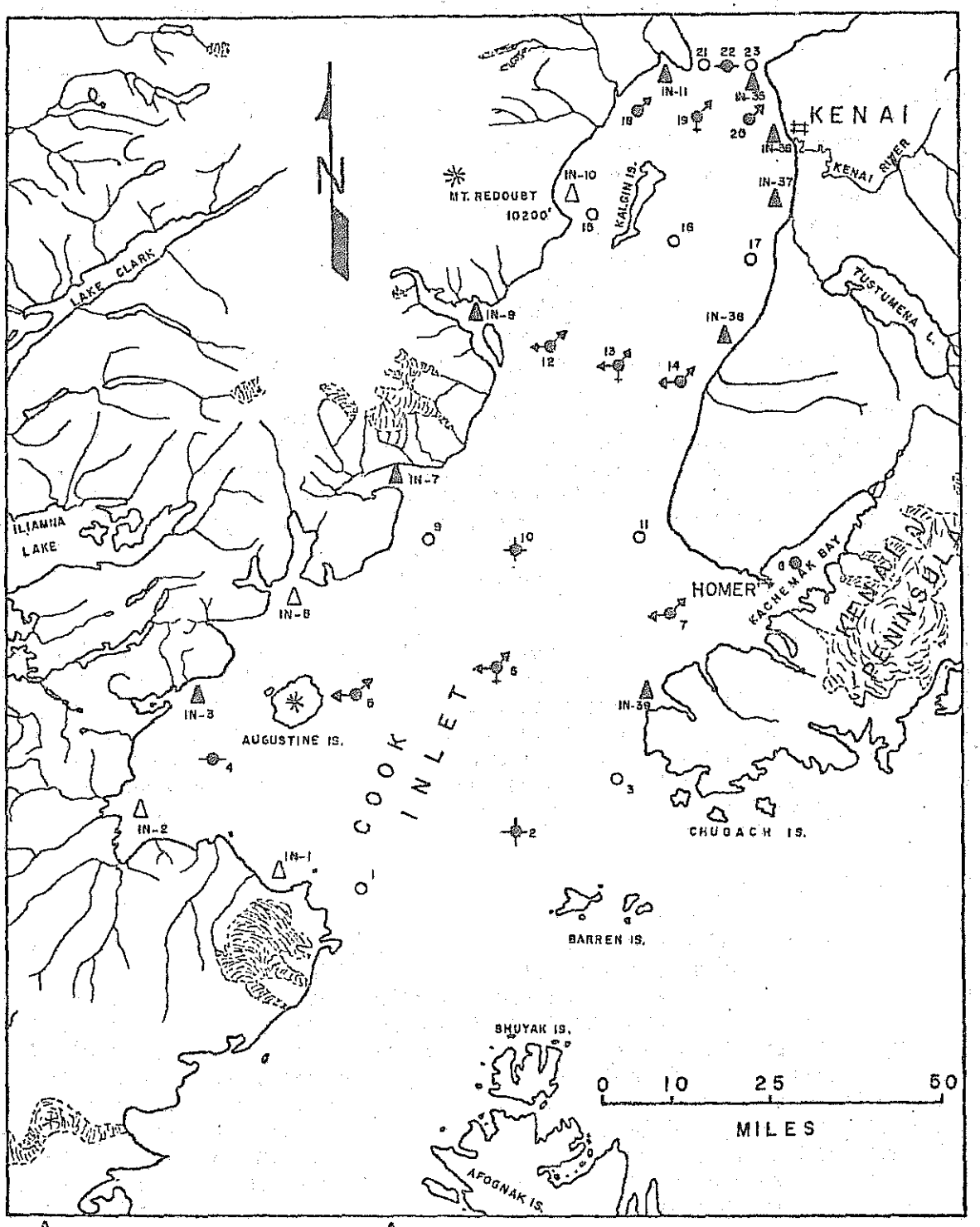
Sampling Activity	Stations New	Stations Existing	Stations Total	Sampling Station Location	Frequency	Remarks
Terrestrial						
River Sediments						
Quantity	2	2	4	See Fig. IV-12, 13	Weekly	Existing Inter-Agency
Characterization	2	2	4		Bi-weekly	Stations
Intertidal						
Sediment Sources - Quantity & Quality				See Figs. IV-12, 13		
Ice	2	-	2		Monthly	Conditions allowing
Shoreline Cliffs	2	-	2		Bi-annualy	
Shoals & Mudbanks	6	-	6		Monthly	
Offshore - Summer						
Core Samples	12	-	12	See Fig. IV-12, 13	Once	
Bottom Sediment Characterization	31	-	31	See Fig. IV-12, 13	Once	
Sediment Transport	18	-	18	See Fig. IV-12, 13	Twice	
Offshore - Winter						
Bottom Sediment Characterization	10	-	10	See Fig. IV-12, 13	Once	
Sediment Transport	6	-	6	See Fig. IV-12, 13	Once	

FIGURE IV-12



LOCATION OF PROPOSED GEOLOGIC DATA COLLECTION STATIONS, UPPER COOK INLET

FIGURE IV-13



△ PROPOSED GEOLOGIC SAMPLING STATION ▲ FIRST SAMPLING YEAR GEOLOGIC STATION

FIRST SAMPLING YEAR SEDIMENT TRANSPORT STATION SUMMER, WINTER

FIRST SAMPLING YEAR CORING STATION

○ PROPOSED AND FIRST YEAR GEOLOGIC STATION SUMMER, WINTER

LOCATION OF PROPOSED GEOLOGIC DATA COLLECTION STATIONS, LOWER COOK INLET

PHYSICAL AND CHEMICAL DATA COLLECTION PROGRAMS

Introduction

Physical and chemical conditions are probably the most important factor in describing the water quality resources of the Cook Inlet estuarine environment in that physical condition and chemical constituents affect the biology and utilization of the Inlet waters for beneficial uses. However, specific objectives for collection of baseline physical and chemical data are hard to define as little is known about existing conditions or can be predicted regarding additional demands which will be placed on the Cook Inlet estuarine system. For this reason a broad approach should be undertaken to provide sufficient data on the physical and chemical characteristics of the total Inlet. The following section will present a brief outline and description of important parameters that should be measured. Because of the large number of parameters that describe the physical and chemical environment, the approach taken in this chapter will be to investigate important parameters on a broad scale in a pilot investigation. The results from this program will point out directions and additional studies that should be undertaken toward a more definitive description of the Inlet water characteristics.

The existing data and studies conducted within the Inlet will be reviewed and a preliminary data collection program will be proposed. A brief mention of the more specific and involved data collection programs will be included. It is desirable to develop a mathematical simulation model to predict and study the interrelation of chemical and physical characteristics. The basic requirements and inputs for the model will also be presented within this chapter.

Types of Data

The physical and chemical characteristics of the waters of Cook Inlet are described by a number of parameters. Before the needs and requirements of the data are discussed, the types and classification of physical and chemical data should be presented. Table No. IV-6 contains the types of data in outline form. It should be noted that the table is not all-inclusive of the many different types of data, but attempts to present the more common and most important classes. Also, due to restrictions of the proposed data collection programs, it will not be possible to sample and analyze for every type of data listed in the table. The table is as complete as possible so that the reader can be more informed while reading further in this section.

Measurements of temperature, density, stability, and the salinity of estuarine waters determine the mixing phenomenon prevalent in Cook Inlet. The stratification of the inlet waters both vertically and laterally affects the sediment transport, the distribution of plankton, and

TABLE IV-6
PHYSICAL AND CHEMICAL DATA REQUIREMENTS

- Physical Data
  - Temperature
  - Density
  - Stability
  - Dissolved Oxygen
  - Sea Ice Characteristics
  - Transparency
  - Turbidity
  - Color
  - Diffusion Characteristics
  - Suspended Particulate Matter
- Chemical Data
  - Relating to Circulating and Mixing Processes
    - Salinity
      - Cations
      - Anions
    - Tritium
  - Relating to Biological Processes and Eutrophication
    - Phosphates (various forms)
    - Organic Nitrogen
    - Nitrites
    - Nitrates
    - Ammonia
    - Silicates
    - pH
    - Trace Elements
    - Dissolved Organics
    - Alkalinity
  - Relating to Pollution and Waste Discharges
    - (in addition to data relating to biological processes and eutrophication)
    - Carbon-12. -13
    - BOD
    - COD
    - Petroleum Products
    - Toxic Materials
      - Pesticides
      - Industrial Chemicals

the supply of food and nutrients to benthic organisms and plants.

Transparency, turbidity, and the types and quantity of suspended particulate matter affect the amount of solar radiation below the surface of the water available for photosynthesis. Also, the turbidity of the water affects the use of estuarine waters by the petroleum industry for injection into oil-bearing sands. The formation and movement of sea ice contribute to sediment transport and salinity changes within the inlet as well as acting as a hindrance to transportation and construction of off-shore facilities such as docks and oil platforms.

Perhaps the most important factor, and one which is used to characterize the estuarine environment as opposed to fresh water or oceanic environments, is salinity, and is defined either as the total amount of dissolved substances in one kg. of sea water, or the sum of the various salt concentrations in sea water. The former definition is the total salinity and the latter definition is the true salinity. Sea water is composed of cations and anions. The cations are sodium, potassium, magnesium, calcium and strontium; the anions are chlorine, bromine, flourine, sulfate, bicarbonate, and boric acid. These cations and anions, along with the hydrogen and oxygen, make up the major components of sea water. Within an estuary the salinity varies from that of fresh water to that of the ocean. Tritium is present in traces in both continental runoff and ocean water but in different concentrations. Measurements of these differences show promise of being useful in determining estuary flushing rates.

Phosphates, nitrates, and various trace elements are valuable as biological nutrients, while ammonia and other dissolved organic materials are energy sources for estuarine organisms.

Certain chemical constitutents are useful in monitoring the pollution and waste discharges entering the estuarine waters. Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and dissolved oxygen are standard tests conducted on waste effluents. Carbon-12 and Carbon-13 measurements show promise of separating naturally occuring petroleum seeps from petroleum spills from platforms and industrial waste discharges. Materials such as pesticides and certain heavy metals are toxic to organisms and plant life and are monitored both in effluents and also in receiving waters.

Data Needs and Requirements

The factors affecting the acquisition of chemical and physical data fall into two general categories: (1) data needed to define the basic environment of the Inlet waters so that the changes within the environment due to naturally occurring or man-made influences can be

measured against the baseline characteristics now present; (2) data needed to evaluate certain problems that are now occurring and are restricting the beneficial uses of certain sections of the Inlet or are thought to affect the biological characteristics of the Inlet adversely. These requirements are discussed in a separate section "Special Studies" located at the end of this Chapter.

There is almost nothing known of the major heat or chemical budget of the Inlet waters. Data are required in every category presented in the preceeding table. A mathematical simulation model developed from the existing data on currents, temperature and salinity would guide and evaluate the effect of a preliminary sampling program within the Inlet waters. Information on the chemical and physical conditions of rivers and wastes now entering the estuary would be inputs to the model. As the data and results of preliminary Inlet-wide sampling programs are evaluated, refinements in the simulation model and in new field sampling programs will lead to more accurate determinations of the physical and chemical characteristics of the Inlet waters.

Measurements relating to biological processes and bearing some connection to eutrophication and pollution should be conducted on an Inlet wide scale. The data requirements would fall within the chemical budget studies discussed above but emphasis should be placed on nutrients, particularly phosphate and nitrate. Measurements should be conducted on constituents relating to phytoplankton growth, namely dissolved organic carbon, dissolved oxygen, and alkalinity and pH for Carbon-14 uptake studies of primary production.

The second category of data needs deals with smaller scale processes within Cook Inlet and relates to more specific pro lems. Cook Inlet is developed to a certain point already and industries and municipalities are injecting waste products into the Inlet. It is necessary to determine the effect of these wastes on the environment now so that the natural conditions can be separated from the manmade changes if possible. The following problems are now occurring and interest is expressed in the need for these to be further investigated. Studies to investigate these specific problems are described in the following section "Special Studies."

The presence of petroleum and petroleum-based products in the Inlet waters is a major source of concern and controversy. Oil has a lethal effect on ducks and sea birds, however, it is not known whether plankton and benthic organisms are adversely affected by the petroleum products. Detergents and dispersents used in other parts of the world have been shown in some cases to be toxic. The Torrey Canyon wreck off

the shores of the British Isles is perhaps the best known and well documented incident of this type. It was found that the detergents used were, in general, more damaging to the biota than the oil released from the wrecked tanker. Oil spills have occurred in Cook Inlet and are expected to happen occasionally due to ship wrecks and pipeline breaks wherever the petroleum reserves of Alaska are developed. It is also believed that naturally occurring oil seeps are present on the Inlet floor. Data are needed on the effects of petroleum and dispersants on the biota of the Inlet. The hydrocarbon level of the Inlet waters should be investigated and monitored. Data from field studies on effects of dispersants and other methods of oil clean-up and removal should be obtained to determine the best methods of removing the petroleum spills. The Inlet floor should be investigated to locate oil seeps. Techniques for quantitative measurements of petroleum derived additions to the Inlet have been developed and are related to the ratios of Carbon-12 and Carbon-13 measurements.

The City of Anchorage is presently discharging raw sewage to the Inlet near the junction of Knik and Turnagain Arms. Plans have been developed to enlarge the sewage collection system, construct a primary treatment plant and discharge primary treated sewage through a submarine outfall off the shoreline at Point Woronzof. It has been the policy of the Federal Water Pollution Control Administration to require secondary treatment in general and allow primary treatment as the minimum acceptable. The construction of the outfall is scheduled to be completed in approximately four years. Investigations of the water quality in the upper Inlet under the influence of raw sewage will yield valuable information on the effect of removing a portion of sewage solids through primary treatment as the new system is put into operation. It is expected that the ecology of the Inlet in the Anchorage area will change to a degree with increased treatment of the sewage and the change in location of the sewage outfalls from several shore points to a single source. Water quality investigations before and after the primary treatment of Anchorage sewage will yield data that can be evaluated to determine the projected effect and need for secondary treatment.

Review of Existing Data and Studies

Table No. IV-7 lists reports and references relating to existing studies and containing pertinent information on the chemical and physical characteristics of Cook Inlet. Present physical and chemical data fall far short of that required to define the basic estuarine budgets.

The majority of chemical and physical oceanographical studies have been conducted by the Institute of Marine Science during the summers of 1966, 1967 and 1968. Several of the cruises were conducted in conjunction with the ships Pathfinder and Surveyor II of the U.S. Coast and Geodetic Survey. A specialized investigation was conducted in the vicinity of the Forelands area to determine the effect of a proposed ammonia waste outfall of the Collier Carbon and Chemical Company. These

TABLE IV-7

REPORTS AND PUBLICATIONS DEALING WITH PHYSICAL AND CHEMICAL OCEANOGRAPHIC DATA COLLECTION PROGRAM

Reports and/or Publications	Agency or Author	Remarks
Reports Containing Specific Data on Cook Inlet		
Oceanography of Cook Inlet [164]	Institute of Marine Science	Contains oceanographic data for Collier Carbon and Chemical Co. effluent site.
Clay-Organic and Inorganic-Organic Associations in Aquatic Environments, Part II [22]	Institute of Marine Science	Report contains an article on currents, sediments and oceanography of Cook Inlet.
Greater Anchorage Sewage Study [184]	Tryck, Nyman & Hayes and Stephsen & Thompson, Consulting Engrs.	Contains data relative to discharge of primary treated sewage to Cook Inlet.
Geology and Hydrocarbon in Cook Inlet Basin [93]	American Association of Petroleum Geologists	Hydrocarbons in Cook Inlet Basin.
Descriptive Oceanography of Cook Inlet [165]	Institute of Marine Science	Oceanographic Information.
Quality of Surface Waters of Alaska, 1961-63 [101]	U.S. Geological Survey	Chemical and Physical data on Rivers in Cook Inlet Basin.
Reports and Publications Containing General Information on Study Area		
22, 46, 48, 57, 62, 71, 75, 76, 85, 101, 108, 144, 155, 160, 184, 191, 192		
Publications and Texts Dealing with Subject Area		
6, 14, 56, 68, 84, 88, 95, 99, 102, 127, 138, 151, 159, 162, 174, 177, 189, 198, 199, 200, 210, 211		

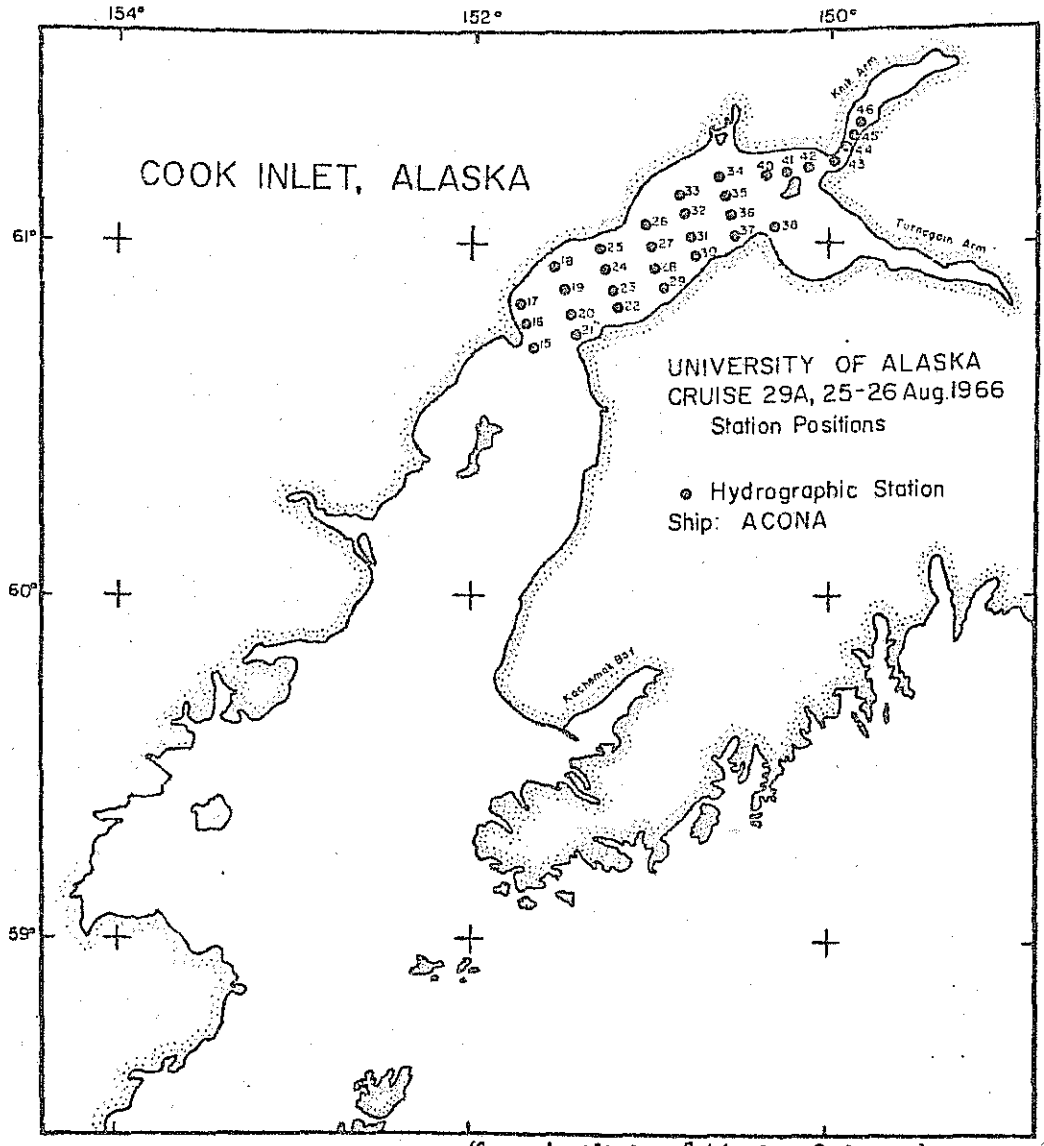
investigations and cruises will be described in greater detail later in this section. Several oil companies have conducted studies on Cook Inlet waters to determine the feasibility of injecting Inlet waters into oil sands to maintain petroleum flows from the oil sands. The Institute of Water Resources investigated low temperature BOD reactions relating to the proposed primary treatment and release of Anchorage sewage to the waters of Knik Arm and upper Cook Inlet.

In addition, certain rivers flowing into Cook Inlet are monitored by the quality-of-water programs of the U.S. Geological Survey. The rivers which have been characterized by chemical and temperature data are the Anchor River, Ninilchik River, Knik River, Matanuska River. Campbell Creek near Anchorage, Chester Creek at Anchorage, Ship Creek near Anchorage, Nuka River near Homer, Swentna River, Deep Creek near Ninilchik, Placer River at Portage, Twenty Mile River near Portage, Susitna River near Oenali, Cantwell and Gold Creek have been sampled for chemical analyses but data are not complete or sufficient to glean much information on the quantities or quality of water entering Cook Inlet. The Inter-Agency Ten Year Plan Report has described and located important quality-of-water stations within the Cook Inlet basin and the existing sampling stations and the proposed sampling stations in the basin as described in the ten year program are shown on Figure IV-4 . The station key numbers refer to descriptions of the stations and can be found in the Inter-Agency Report.

Since 1966 the Institute of Marine Science of the University of Alaska has been occupying standard oceanographic stations within the Inlet. Figures IV-14, through IV-20 show the station locations. The 1968 data have not been completely reduced at this time. A major portion of these data consists of temperature and salinity at selected depths. A few nutrient values are available in these data.

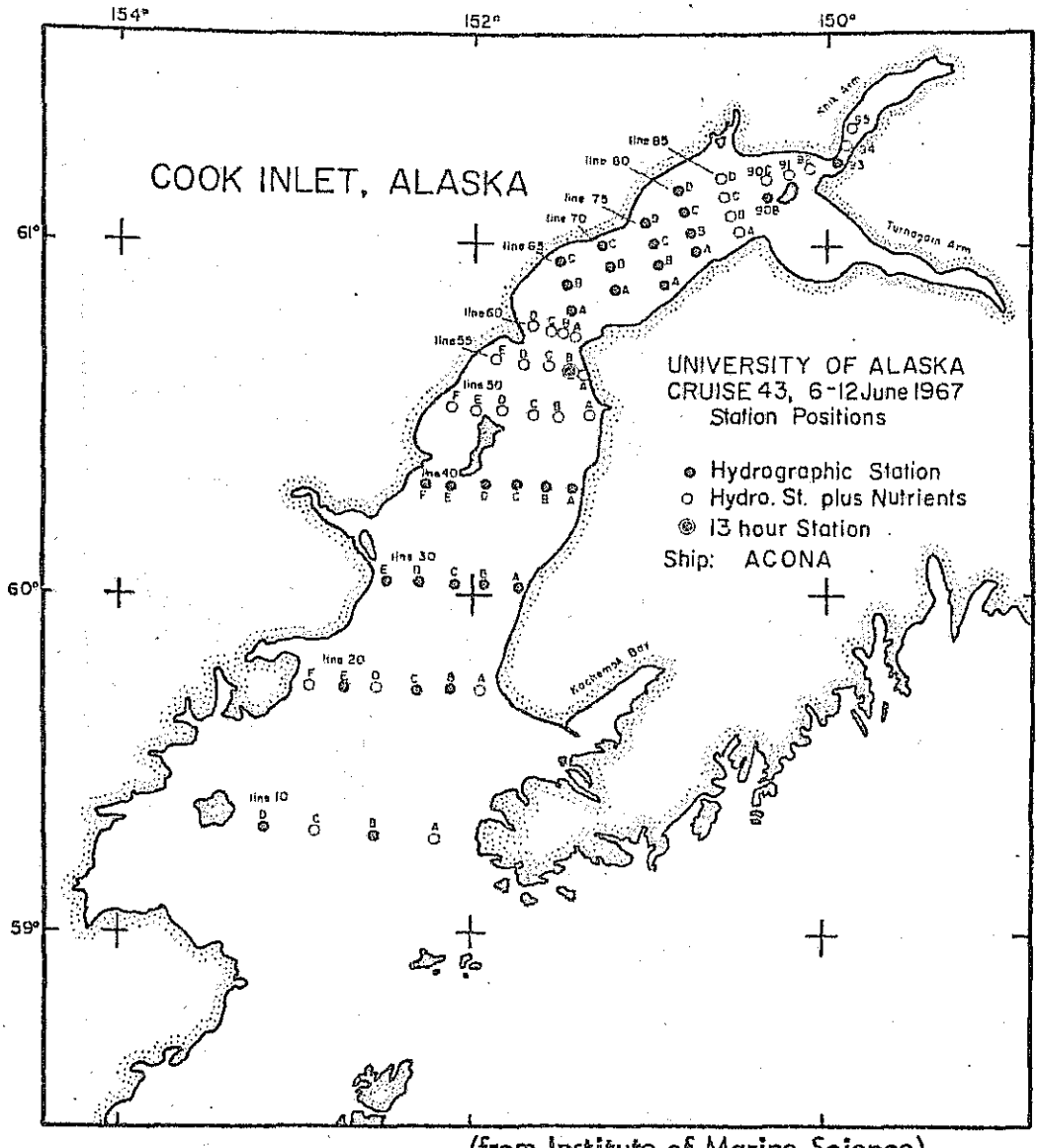
The report "Oceanography of Cook Inlet," listed in the table of reports, presents the results of an oceanographic investigation on the diffusion characteristics and other pertinent studies for the discharge of an ammonia waste into Cook Inlet near the Forelands. The investigation was started in 1967 and included a general study of the Inlet with special reference to the area of the outfall site. Studies were also included to show the effect of the waste material on the suspended sediments and the marine biota of the Inlet. This study has been the most comprehensive to date and the report should be included as recommended reading.

Collier Carbon and Chemical Corporation has undertaken a sampling program to obtain background oceanographic information pertinent to the safe operation of an outfall diffuser system for dispersal of process waste. Data have been gathered at stations located in the region of the Forelands. Monthly samples have been obtained from certain stations only. Data gathered consist of temperature, salinity, and nutrient chemistry.



(from Institute of Marine Science)

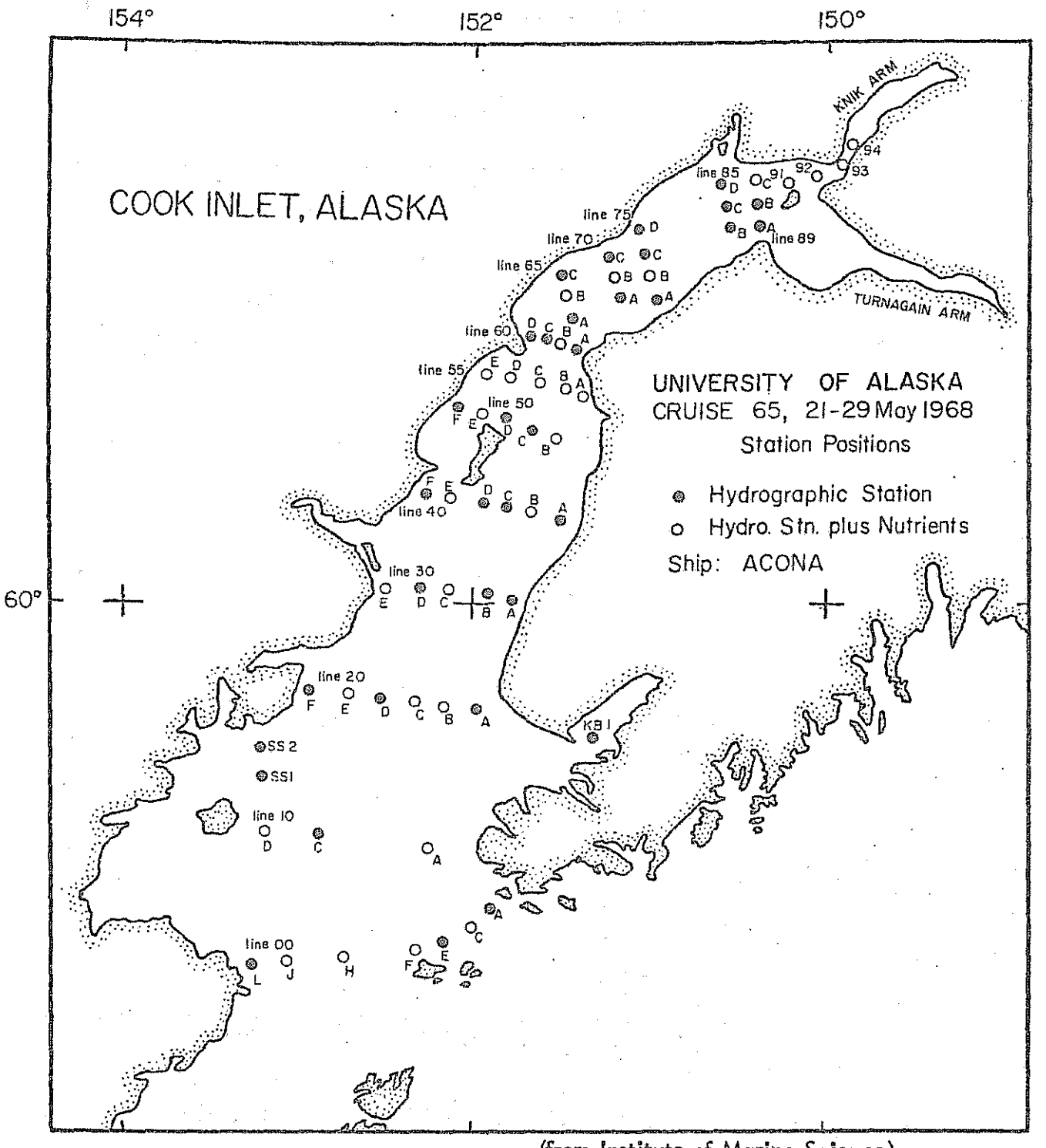
OCEANOGRAPHIC CRUISE STATIONS IN COOK INLET



(from Institute of Marine Science)

OCEANOGRAPHIC CRUISE STATIONS IN COOK INLET

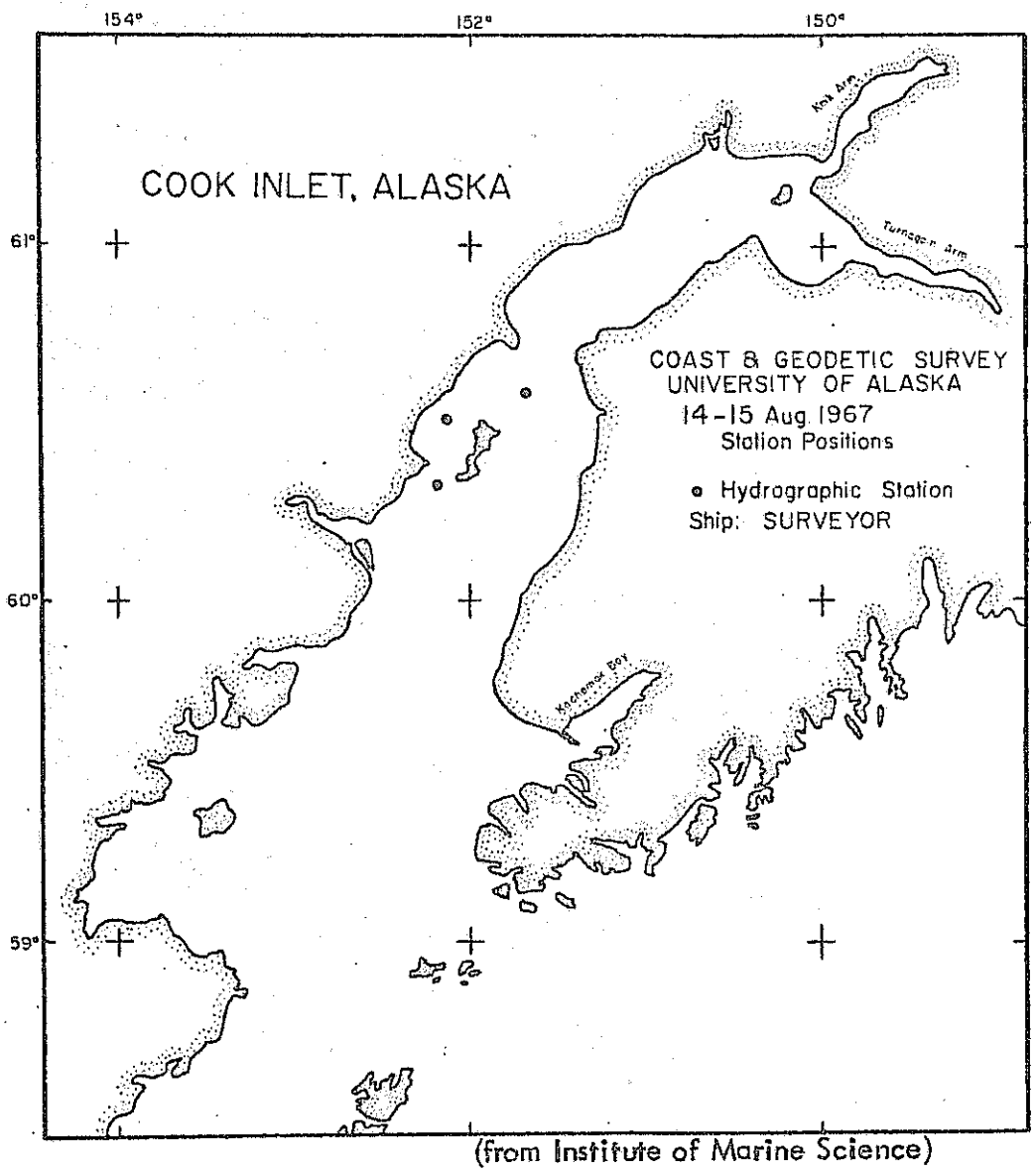
FIGURE IV-16



(from Institute of Marine Science)

OCEANOGRAPHIC CRUISE STATIONS IN COOK INLET

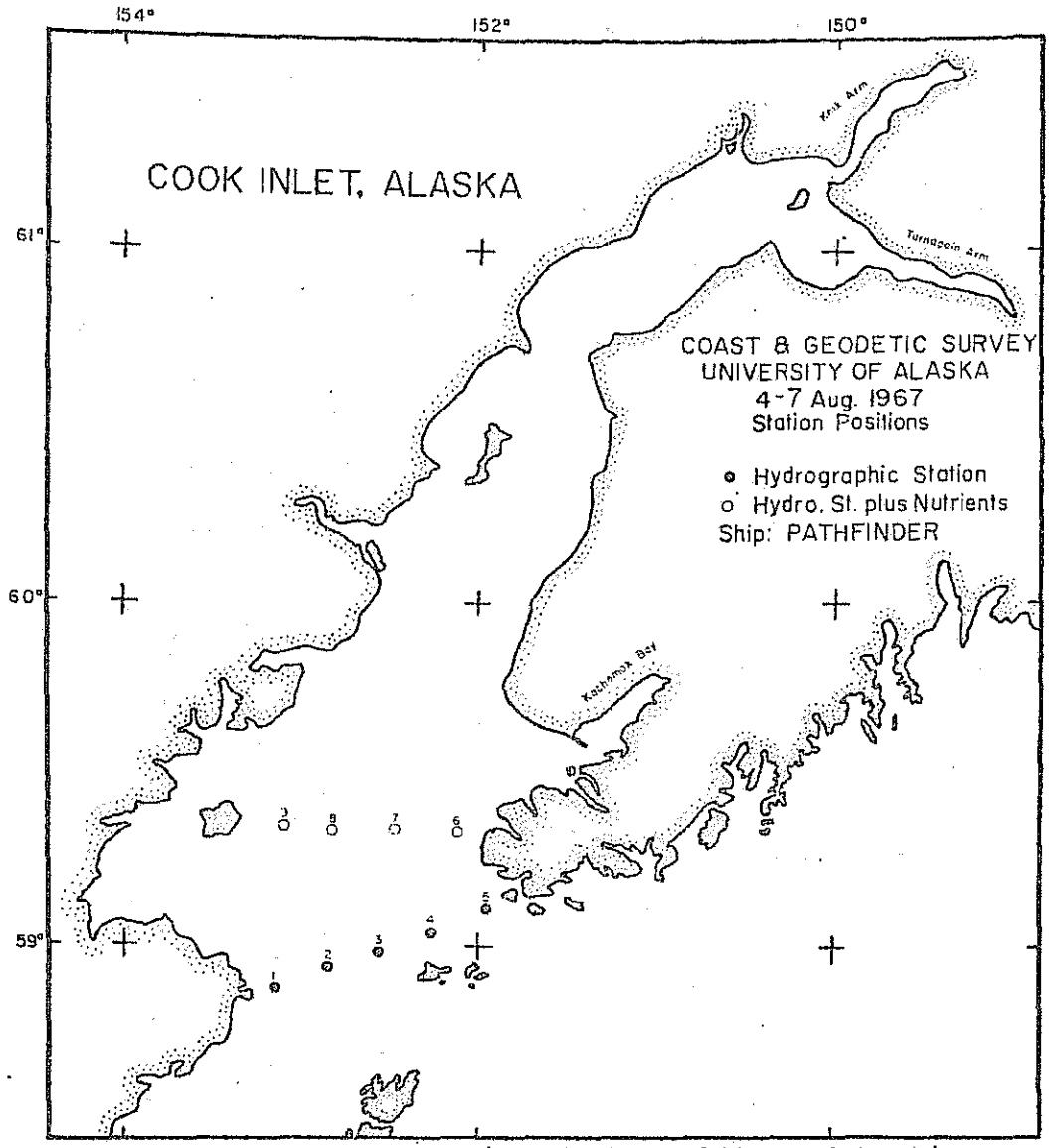
FIGURE IV-17



(from Institute of Marine Science)

OCEANOGRAPHIC CRUISE STATIONS IN COOK INLET

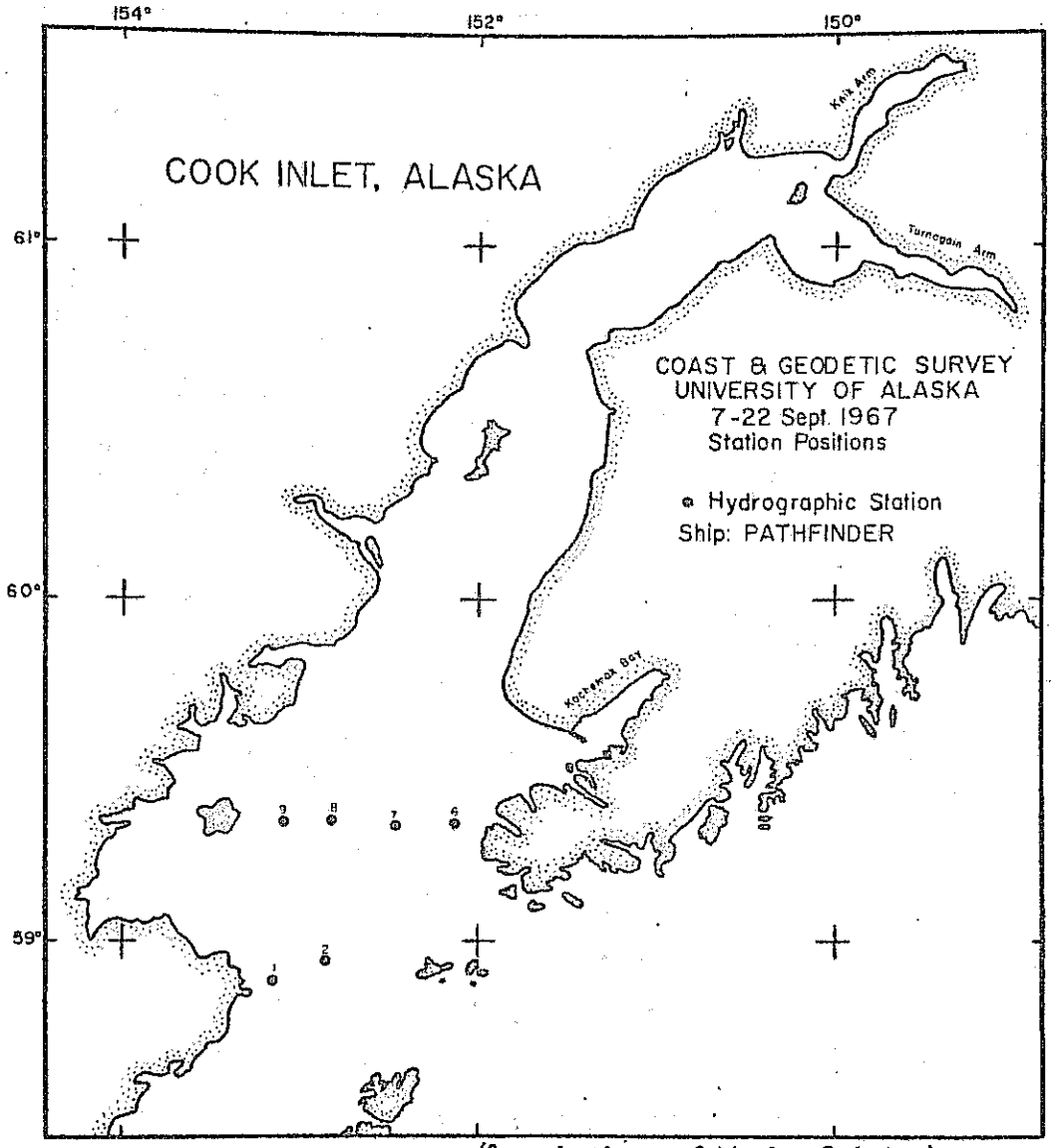
FIGURE IV-18



(from Institute of Marine Science)

OCEANOGRAPHIC CRUISE STATIONS IN COOK INLET

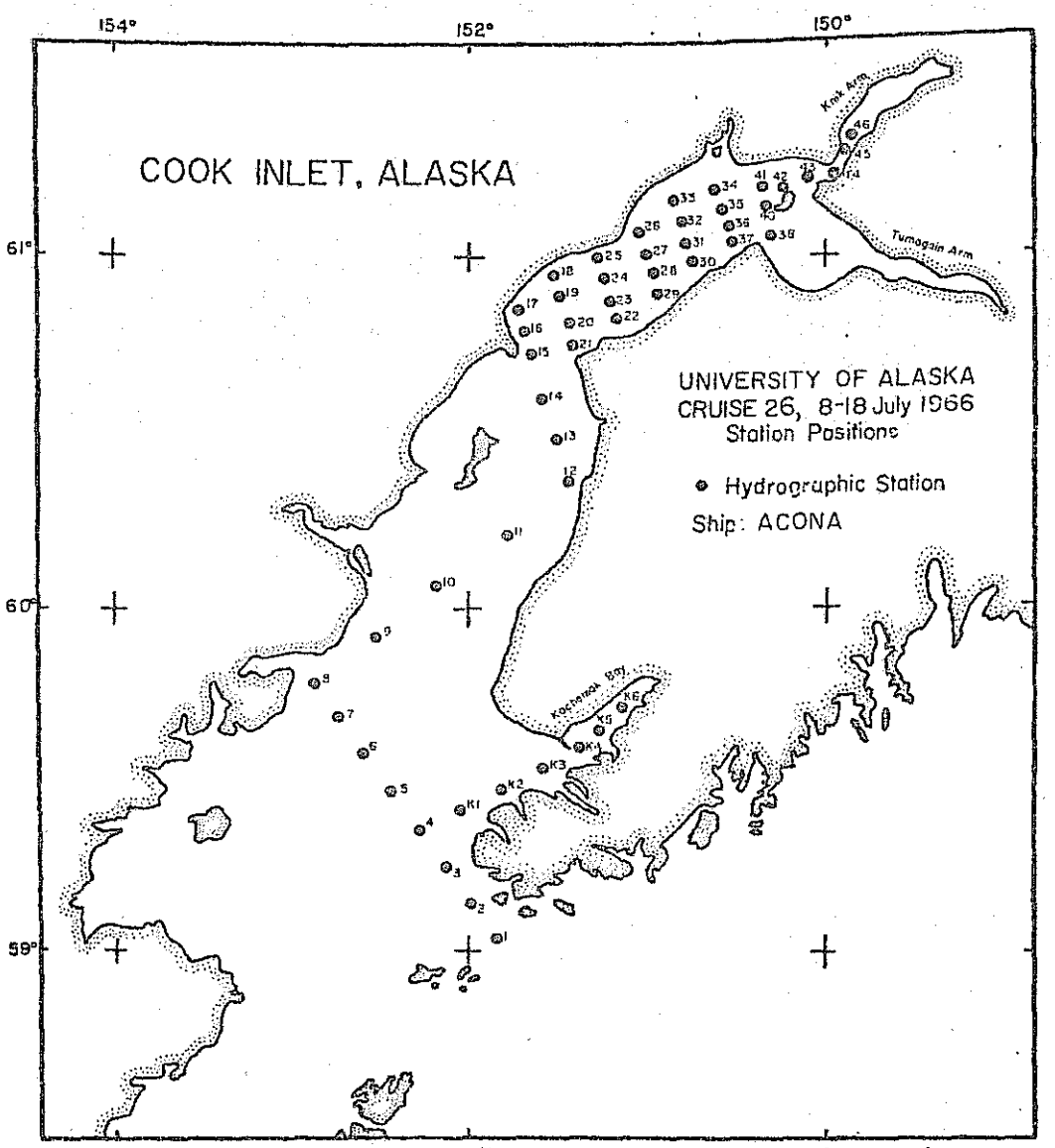
FIGURE IV-19



(from Institute of Marine Science)

OCEANOGRAPHIC CRUISE STATIONS IN COOK INLET

FIGURE IV-20



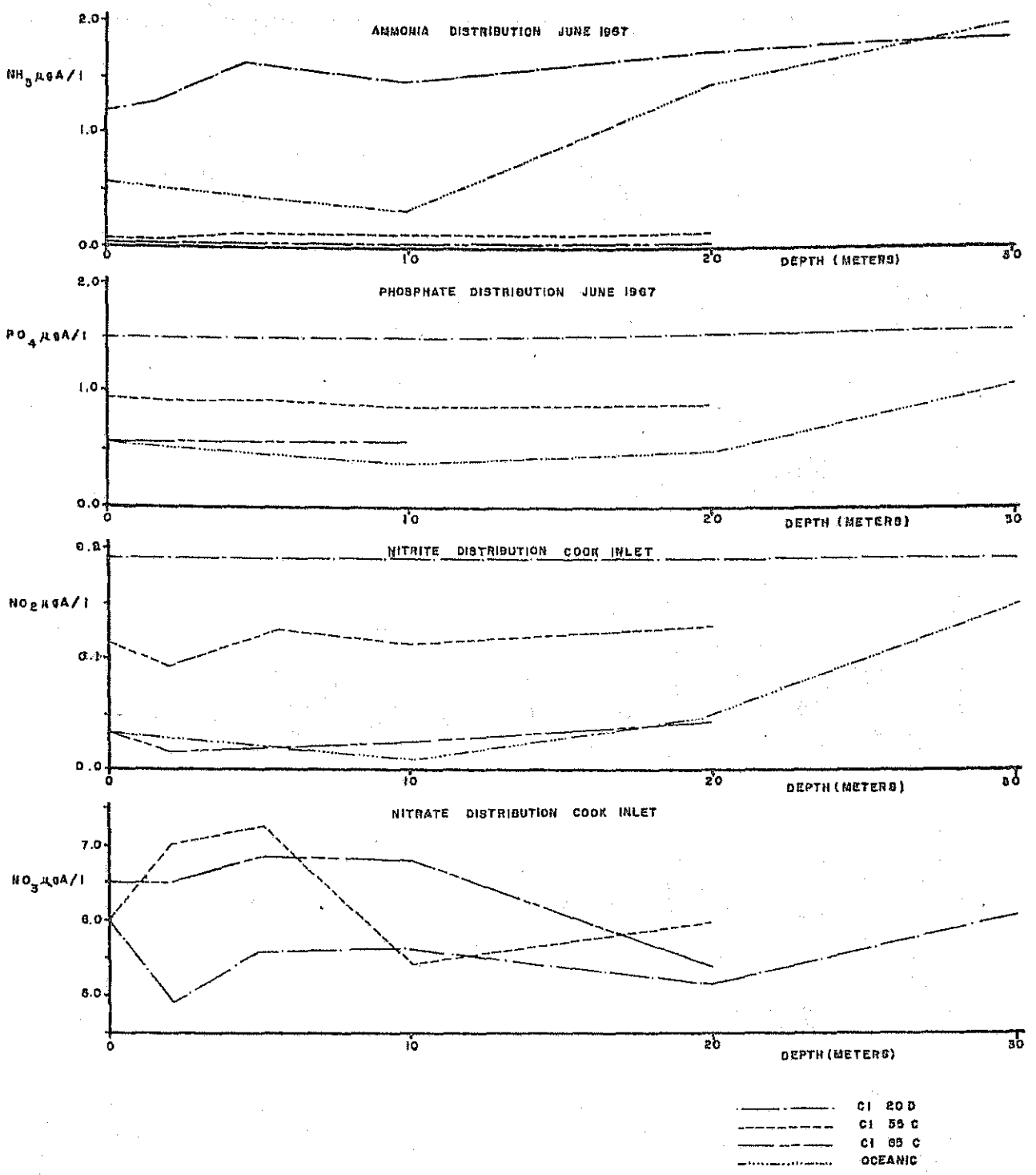
(from Institute of Marine Science)

OCEANOGRAPHIC CRUISE STATIONS IN COOK INLET

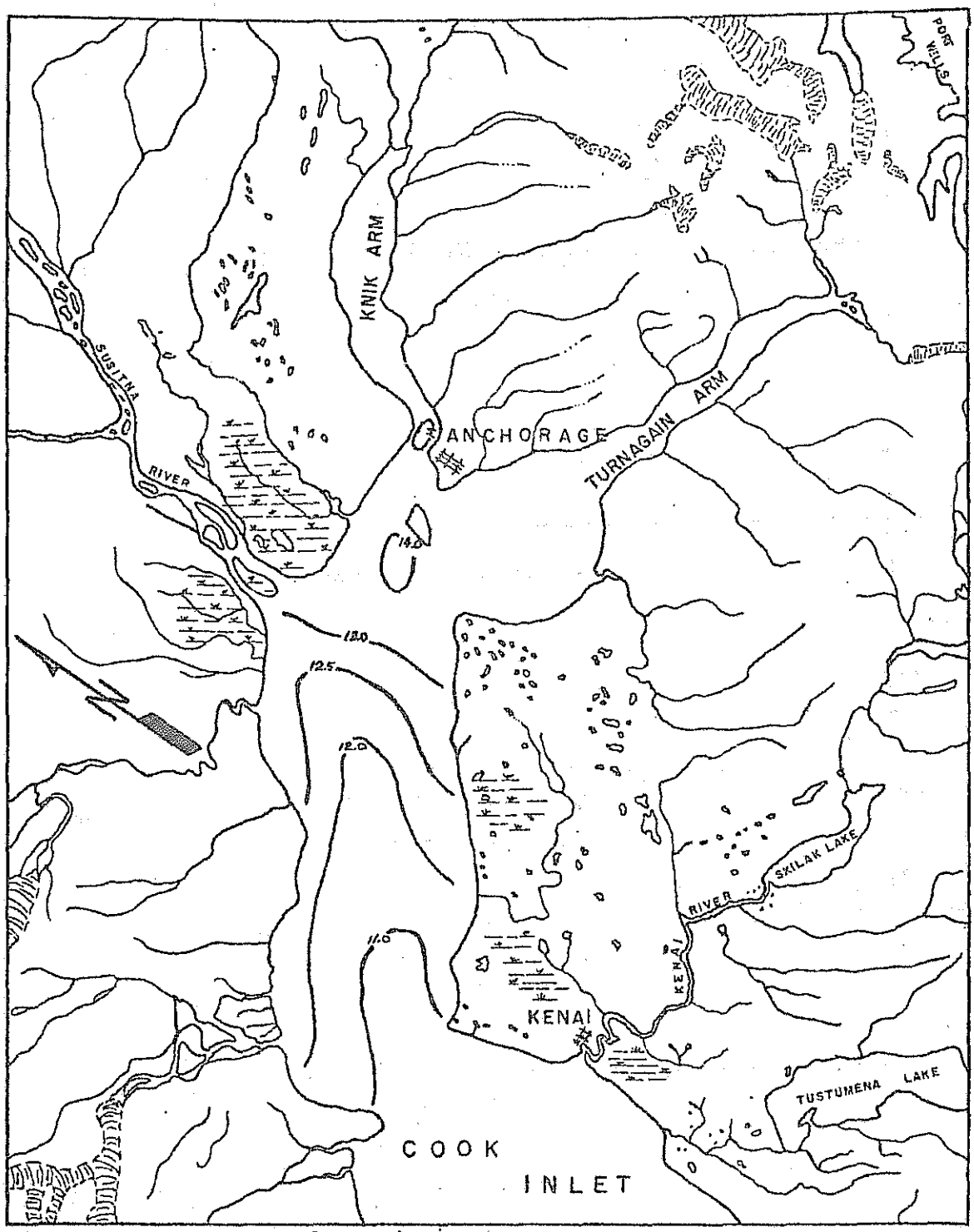
Figures IV-21 through IV-22, and Table No. IV-8 are a summary of the more important characteristics of the physical and chemical constituents of the Inlet waters derived from the oceanographic cruises of the past three years and are taken from various reports prepared by the Institute of Marine Science.

In summary, the physical and chemical data on Cook Inlet waters are fairly complete in parameters dealing with nutrients, temperature and salinity for summer months of June, July and August. Outside of this limited scope of data and during other months, there is a complete lack of information. The onshore programs of water quality monitoring stations included within the Inter-Agency Ten Year Plan report and indicated on Figure IV-4 are felt to be sufficient generally. Several new quality-of-water river stations will be indicated in the data programs proposed within this report, which are not included within the "Ten Year Plan".

FIGURE IV-21



NUTRIENT CONCENTRATIONS IN COOK INLET
(from Institute of Marine Science)



(from Institute of Marine Science)

0 5 10 20
MILES

UPPER COOK INLET
SURFACE TEMPERATURE in °C
17 July - 18 July 1966

TABLE IV-8

pH COOK INLET - June 1967

Depth (m)	pH
Station CI 20 D	
0	8.16
2	8.15
5	8.23
10	8.31
20	8.35
30	8.34
Station CI 55 C	
0	7.99
2	7.97
5	7.99
10	7.99
20	8.02
Station CI 85 C	
0	7.77
2	7.76
5	7.73
10	7.73
20	7.72

Proposed Data Collection Program

To provide sufficient baseline information and to allow accurate analysis of circulation, flushing, and heat and major chemical budgets for the Inlet will require an extensive seasonal sampling program. Since little actual information on the Inlet is available, planning of a final sampling program at this time is impossible. Instead, it is proposed that a multiple phase program be developed where the initial phase will provide sufficient information to plan meaningful data collection.

First Phase. The first phase will be devoted to organization and planning activities.

Second Phase. This initial sampling program will require seasonal sampling of major physical and chemical parameters at stations shown in Figures IV-23 and IV-24. Certain of these offshore stations should be occupied to provide continuous data for at least 14 hours. Concurrent with this sampling program, direct measurements of current velocity and direction should be made. This phase should last until one complete seasonal cycle of data is obtained. Two additional river quality-of-water stations are proposed at the mouth of the Beluga and Susitna Rivers. Existing stations are located on the Matanuska and Knik Rivers to provide continuous quality data during the high flow summer months (Figure IV-23). The intertidal stations shown on Figures IV-33 and IV-24 are biological sampling and inventory stations. During biological sampling activities at these intertidal stations, certain pertinent chemical and physical data will be determined. Table IV-9 summarizes the activities of the second year sampling activities. The types of samples to be collected are divided into physical and chemical data. The specific analyses will be determined at the time of planning the specific sampling activity but the needs and types of data were discussed earlier in this section.

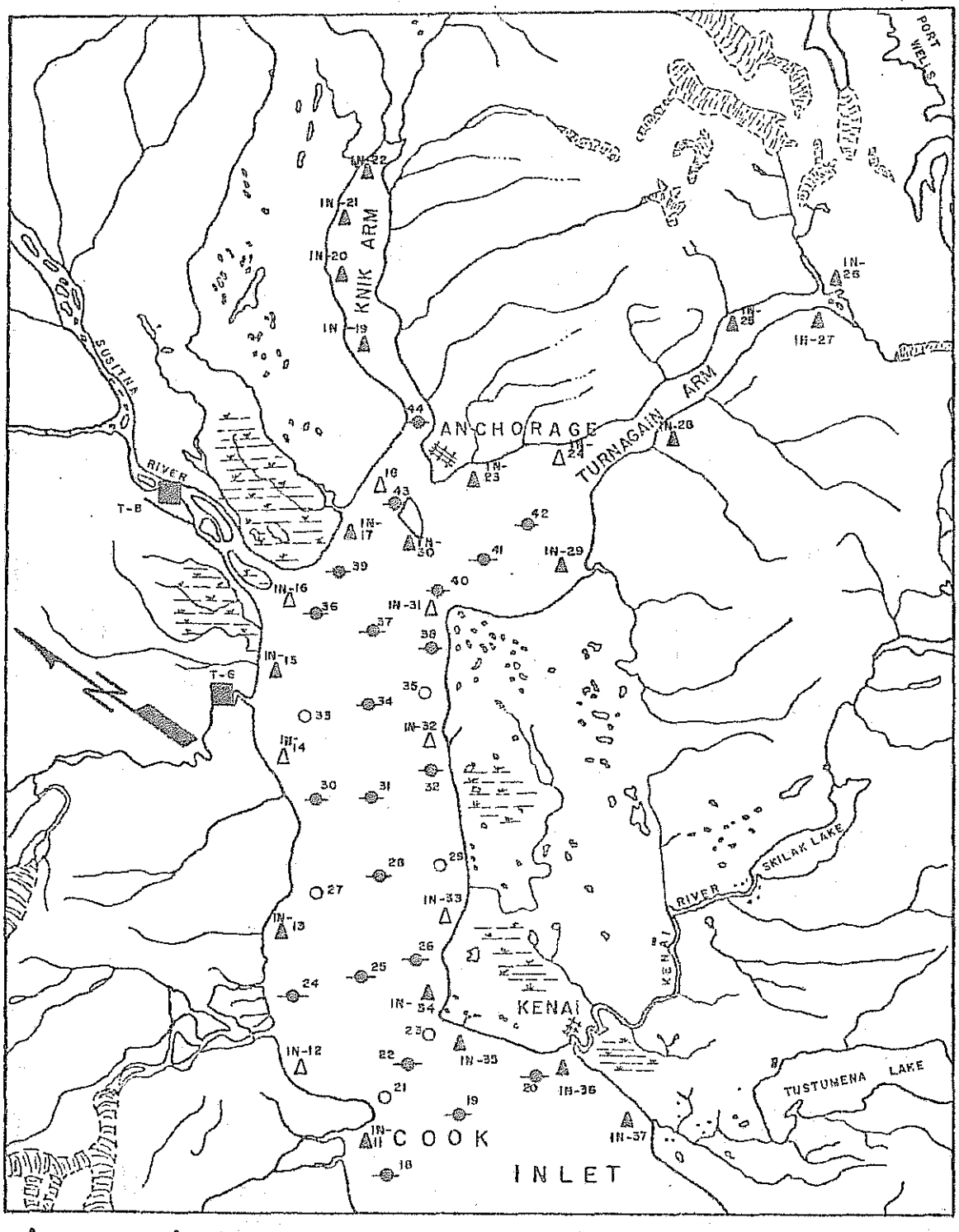
Third Phase. Existing tidal and river flow data will be applied with the data gathered to develop a basic mathematical model. It is not known at this time whether the simulation model developed to define circulation patterns and tidal fluctuations will be adaptable to handling chemical budgets and flush times for the Inlet. Whether two models are required will have to be determined at the time of the proposed program inception. Chemical parameters measured will be examined to determine if a "tracer" is available to test the model for flush times for the Inlet. This basic model should allow calculation of the mass transport and chemical budgets for the upper Inlet and for the total Inlet.

The sampling program will then be modified to provide a complete model of the Inlet. This modified sampling program will not only provide general coverage of the Inlet but will provide for extensive measurement in selected areas. Parameters determined to be important in the formulation of the model will be emphasized although the basic data will continue to be obtained regarding baseline chemical and physical parameters. Offshore sampling will be expanded to the complete grid presented in Figures IV-23, and IV-24.

TABLE IV-9
PHYSICAL AND CHEMICAL QUALITY SAMPLING PROGRAMS
(Second Year)

Sampling Activity	Station New	Station Inter E	Station Inter P	Station Total	Sampling Station Location	Frequency	Remarks
Terrestrial							
River Quality							
Physical	2	3		5	See Fig. IV-23	Bi-weekly	Monthly during winter
Chemical	2	3		5	& Iv-24	Bi-weekly	Monthly during winter
Intertidal							
Estuary Water Quality							
Physical	23			23	See Fig. IV-23 & IV-24	Monthly	Bi-monthly during winter, weather permitting
Chemical	23			23		Monthly	Bi-monthly during winter, weather permitting Selected physical and chemical parameters
Offshore - Summer							
Estuary Water Quality							
Physical	31			31	See Fig. IV-23	Monthly	
Chemical	31			31	& IV-24	Monthly	
Offshore - Winter							
Physical	10			10	See Fig. IV-23	Bi-monthly	
Chemical	10			10	& Iv-24	Bi-monthly	

FIGURE IV-23



△ PROPOSED AND ▲ FIRST SAMPLING YEAR PHYSICAL AND CHEMICAL SAMPLING STATION

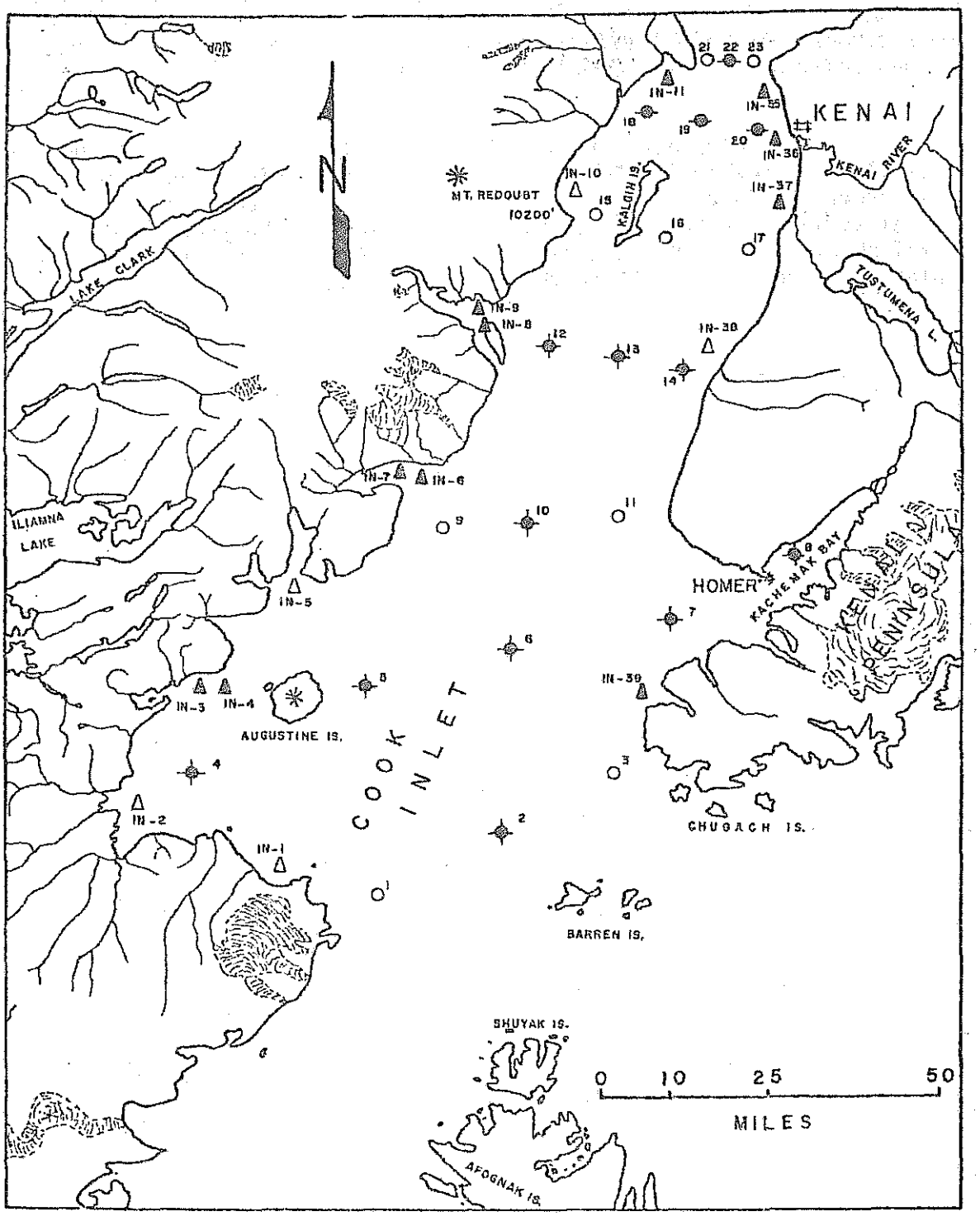
▩ FIRST SAMPLING YEAR STREAM QUALITY STATION

○ PROPOSED AND ● FIRST SAMPLING YEAR PHYSICAL AND CHEMICAL SAMPLING STATION (-● SUMMER)

0 5 10 20
MILES

LOCATION OF PROPOSED PHYSICAL & CHEMICAL DATA COLLECTION STATIONS, UPPER COOK INLET

FIGURE IV-24



△ PROPOSED AND ▲ FIRST SAMPLING YEAR PHYSICAL AND CHEMICAL SAMPLING STATION

○ PROPOSED AND ● FIRST SAMPLING YEAR PHYSICAL AND CHEMICAL SAMPLING STATION (SUMMER WINTER)

LOCATION OF PROPOSED PHYSICAL & CHEMICAL DATA COLLECTION STATIONS, LOWER COOK INLET

Fourth Phase. The additional data provided from the second phase will be used to modify the basic mathematical model. Sufficient information will be available to provide baseline values and to allow with proper laboratory studies, estimates of the impact and distribution of new pollutants of the Cook Inlet system.

It was noted earlier in this section that oil spills have been a problem of concern in Cook Inlet. No one can predict when a spill will occur; however, it is planned that the oceanographic research vessel will be present in the Inlet during most of the year. When a spill should occur, the necessary manpower and equipment will be available to monitor the spill and the effects on the environment.

BIOLOGICAL DATA COLLECTION PROGRAMS

Introduction

In any pollution-oriented study, the nature of the original biota present in the region should be known under the assumption that any change in the environment will have the first impact on the biota.

Cook Inlet, a coastal plain estuary, is an interesting area biologically. The fluctuation in the plankton population with each flood and ebb tide, the light-limiting properties of the sediment load carried in the water, and the well-mixed water column are some of the characteristics of the Inlet which have a direct effect on the distribution and seasonal variation of the plankton population in the Inlet.

It is apparent from a survey of the literature that there is very little information on the distribution of plankton populations or on the subtidal and intertidal benthic organisms in Cook Inlet.

This chapter will discuss the various types of marine biota and briefly describe the interactions between the physical, chemical and biological segments of estuarine ecology. The data needs required to evaluate the biota of the estuary will be presented and the existing data and studies will be reviewed. Finally, proposed data collection programs necessary to describe the nature of the biota now present in the estuary and to measure the changes in the biota caused by changes in the environment will be presented.

Data Need and Requirements

At the present time commercial fishing is the most important activity concerned with the biological environment of Cook Inlet; however, in describing the ecological environment of the estuarine waters, other organisms interact to form a dynamic system. The biological sampling programs presented in this chapter are designed to describe this dynamic system in terms of the populations that inhabit the Inlet waters, the interactions of these populations, and the significance of certain populations in acting as indicators for changes in the ecological environment, either through naturally occuring or man-induced influences. Any study of the biological environment must take into consideration the interaction of the physical and chemical factors that influence the dynamic biological system.

The physical factors that are important in influencing the biota of Cook Inlet are tides, currents, sediments, fresh water inflows, attenuation of light, and climatological conditions of the Cook Inlet drainage basin. The tidal range determines the areas of the shore which are alternately exposed and submerged by estuarine waters. Currents affect the movement of planktonic organisms, and, most important, bring nutrients and food to "sessile," or fixed marine plants and animals. Suspended sediments can reduce the amount of light available for photsynthesis. Bottom sediments can cover benthic organisms and reduce the ability of these organisms to grow and reproduce. Petroleum products released to estuarine waters are possibly adsorbed on sediment particles and carried to the bottom where organism growth can be affected. The structure of the estuary is modified by current-shifted bottom sediments and erosion of bottom sediments due to increased or changed currents can wash away benthic burrowing organisms.

The light that penetrates the water is affected by absorption of the water and the concentration of suspended particles. Phytoplankton will be able to photosynthesize only in the top layers of a turbid estuary and in such an estuary the production of organic matter may be due only to littoral zone plants which may be uncovered by the turbid water. Salt marshes can play an important part in the production of an estuary when algal photosynthesis is reduced by water turbidities. Other physical conditions of an estuary play an important part in the dynamic system, but the above described factors are also to be investigated as parts of other data collection programs presented in this report.

Chemical constituents of estuarine waters are fundamentally important in the size and diversity of biological populations. The types of chemicals and the variation of certain of these factors caused either by naturall occurring changes or man-made pollution can enrich the biota and/or cause it to be irreparably damaged. Dissolved minerals, dissolved organics, dissolved gases, temperature, nutrients, and toxic compounds all affect the biota and their interaction in the ecological environment. Dissolved minerals of biological importance are the minerals comprising the salinity of estuarine waters. The body fluids of marine and terrestrial animals have salinity characteristics similar in types of constituents and concentrations to that of oceans or estuaries. The variation in salinities have a large impact on the viability of marine organisms. Interstitial salinity, the salinity of the pore water in marine bottom deposits, affect the types of benthic organisms inhabiting these sediment deposits.

Organic material enters the estuarine environment from fresh and salt water sources and originates from industrial, municipal, agricultural, and natural sources. There is a demand for these constituents by biological organisms in order to carry out life processes.

The oxygen resource of the estuarine system are by far the most important gaseous constituent. All life processes depend upon oxygen in either dissolved gaseous or chemically combined forms. For the purpose of this discussion, most estuarine forms of life need oxygen in the gaseous form.

The temperature affects the metabolic rate and therefore the oxygen demands of marine organisms. Nutrients are required for growth and also hold the key to incipient eutrophication. Toxic constituents originate usually from industrial waste inputs but also are related to the growth patterns of certain types of algae. There are cases of large numbers of finfish and shellfish dying from toxic compounds given off by these algae. A dynamic biological system study must take into account the various chemical constituents of estuarine waters to account for variations or even the existence of biotic forms in a marine environment properly.

To assess the biotic potential of the Cook Inlet estuary properly and to describe the ecological system, the following types of marine life should be investigated: (1) estuarine vegetation, (2) macrobenthos, (3) microbenthos, (4) fish, (5) birds, (6) parasites, (7) the fresh water component, (8) the terrestrial component, and (9) estuarine plankton. Table No. IV-10 presents a listing of the types and species of estuarine flora and fauna that make up the ecological system. It is not in the interest of this section to describe each specific category of organism, but to inventory and describe the estuarine population. It is not known at this time whether all of the species listed are present in Cook Inlet. Certain classes of the plants and organisms are of special importance and will be discussed. Aside from the initial need to determine what organisms are present within Cook Inlet, certain organisms and plants are thought to be indicators of pollution-induced changes within an estuary. Monitoring the changes in population and viability of these organisms and plants can be an accurate and more effective method of monitoring changes in the water quality of the Inlet.

Commercially, the biota of the Inlet serve as a source of income for commercial fishermen and seafood canneries and processors. Salmon, trawlfish, crabs, and shrimp are now being harvested. Clams are abundant in certain sections of the lower Inlet. The potential of Cook Inlet in being able to produce a commercially valuable harvest of sea food is known in the area of salmon and crabs. Other species have not been investigated extensively enough to assess the total value. Thus, a biological survey of the

TABLE IV-10
BIOLOGICAL DATA REQUIREMENTS

Estuarine Vegetation
- Deep Water Component
- Littoral (near shore) component

Macrobenthos
- Coelenterates
- Turbellarians
- Annelids
- Nemertea
- Extoprocta
- Gastropods
- Lamellibranchs
- Barnacles
- Isopods
- Amphipods
- Shrimps and Prawns
- Crabs

Microbenthos
- Ciliates
- Foraminifera
- Protohydra
- Micro-Turbellarians
- Nematoda
- Micro Annelids
- Ostracods
- Benthic Copepods
- Halacarid Mites

Fish
- Estuarine Teleosts
- Estuarine Elasmobranchs
- Cyclostomes

Birds

Parasites and Epibionts
- Parasitic Coelenterata
- Platyhelminthes
- Parasitic Nematodes
- Parasitic Crustacea
- Other Parasitic Arthropods
- Parasitic Fungi
- Parasites of Migratory Fish
- Parasites in the Brackish Waters

The Fresh Water Component
- Species found in marshes
- Species found in rivers

The Terrestrial Component

Estuarine Plankton
- Phytoplankton
- Zooplankton
- Planktonic Copepods
- Mysidacea

Inlet would serve an immediate practical purpose in defining the commercial value of the species present.

In working within an area such as Cook Inlet where little is known about the species present or the ecology of the environment, certain information must be gathered. First, the different populations that inhabit the estuarine environment must be cataloged; second, studies must be conducted to determine the interaction, and factors controlling the diversity of these populations; and third, to determine the impact of changing water quality the biological environment must be related to the chemical and physical characteristics ecologically.

It is desirable to describe briefly some of the more important classes and the importance of these organisms and plants as they relate to the ecosystem and changing water quality.

Estuarine vegetation assumes its most important role in the shoreline and littoral zone where it is able to receive solar radiation for photosynthesis. Intertidal algae, rooted plants in shallow water, or marine growths attached to surf-beaten rocks serve as food for birds or other organisms. These plants also stabilize shore deposits and contribute to the eutrophication of an estuary. Macro and micro benthic organisms are bottom-dwelling organisms and are either sessile (fixed) or motile, being able to move around at will to search for food. Fish, both commercially and ecologically, are important. Commercially, the importance of the fishing industry has been well documented. Ecologically, fish are a link in the food chain and are affected by changes in water quality both in the sizes of individual population and the diversity of species.[9] Estuarine birds include: (1) land birds such as crows, ravens, eagles, and jays, (2) sea birds such as gulls, kittiwakes, cormorants, and (3) land-based birds which feed primarily near shores and in marshes. These include ducks and geese.

The problems encountered by animals living in estuaries are in varying degrees related to the presence of parasites and epibounts. Parasites either are external or internal to the host but in each case derive food from the body of the host organism. Epibounts attach to the body of the host organism but derive their food from the environ ment surrounding the host. The study of parasitic organisms relates to the ecology of the entire plant and animal system. Parasites can be carried through major sections of food chain and in some cases can be harmful to humans.

The fresh water component of an estuary includes insects such as mosquitoes, water beetles, water bugs, and crustacea. Most of the crustacea living in fresh water are marine forms that penetrate to varying degrees into brackish waters. Marine forms of animals may intrude into a fresh water habitat or the reverse may occur, often depending on the competition within the habitat from other forms. Although not located within the Inlet waters, the marshes within the Susitna Lowland are variable in their salinity due to tidal flooding during extreme high spring and fall tides. At other times of the year the marsh waters decrease in salinity and the fresh water organisms may abound.

The vegetation of an estuary, particularly in the region of a salt marsh, shows a transition from aquatic to terrestrial plant communities. Progressive adaptation to submersion is facilitated through the action of spring and fall neap tides, providing an opportunity for terrestrial animals to penetrate down the shore [65].

Plankton as primary producers are the most important subject of study within Cook Inlet. Plankton are floating organisms whose movements are more or less dependent upon currents. Phytoplankton are classed as plants containing chlorophyll and depend upon light to carry out life functions. Zooplankton are minute animals which have a capability for active swimming motions. Plankton as a whole are unable to make any appreciable progress against appreciable currents. Studies to determine the types and diversity of both phytoplankton and zooplankton should be conducted. The spacial distribution and seasonal variation may also be important and should also be investigated.

Foraminifera are minute single-celled animals possessing shells called tests, and are classified under Phylum Protozoa, Class Rhizopoda and Order Foraminifera. Members of the Order Foraminifera live both in the water column as plankton and on the sea floor as benthos. Foraminifera may be important sources of food for some marine animals. Past studies have indicated that Foraminifera are indicators of environmental factors such as temperature, depth, salinity, and bottom sediments. It seems hopeful that some correlation between the distribution of Foraminifera and properties of an environment which has been modified by man may be made [5].

Along with plankton, benthic organisms are of great interest in Cook Inlet. Benthic animals can be divided into two divisions--

macrobenthos, animals large enough to be retained on a sieve with a mesh of 1 mm, and microbenthos, or animals passing the 1 mm mesh. Shrimps and crabs are harvested commercially within Cook Inlet and the populations have received some attention at present as major macrobenthic species. The macrobenthos and microbenthos should be investigated in both the subtidal and intertidal zones with respect to population size and spacial distribution of each species. Attention should be given to determination of important indicator species that are sensitive to pollutional changes.

Review of Existing Data and Studies

Table No. IV-11 lists reports and publications containing specific data relevant to Cook Inlet. Numbered reports and tests within the table refer to references within the bibliography which relate to the subject. These are recommended for a more intensive background in the subject. In some cases, the information is not necessarily specific to data on the Cook Inlet waters.

Commercial fishing interests presently and in the past have been the dominant factor in biological studies at Cook Inlet. Both the U. S. Fish and Wildlife Service through the Bureau of Sport Fish and Wildlife and the Bureau of Commercial Fisheries and the Alaska Department of Fish and Game have been active in Cook Inlet to varying degrees. Reference is also made to the Appendix of this report describing in some detail the research programs carried out in the past few years and also proposed for the Kasitsna Bay field research station of the Bureau of Commercial Fisheries of the U. S. Fish and Wildlife Service. The Bureau of Commercial Fisheries has instituted a proposed research program in the Kachemak Bay and adjacent Cook Inlet area to develop an ecological simulation model of that area and will include studies on king crab and shrimp. The program will include chemical, physical and biological oceanographic studies and physiological studies on the above organisms. The program will take place over approximately the next five years. Also, research has been carried out over the past five years on the life histories, ecology, behavior, and exploratory fishing for shrimp. Fecundity studies on king crab and shrimp were carried out during the 1967-1968 season.

The Institute of Marine Science [164] has done a study on the oceanography of Cook Inlet with reference to the effluent of the Collier Carbon and Chemical plant in which there was a section dealing with some physiological studies on marine plankton collected from Cook Inlet. Natarjan of the same Institute has investigated the seasonal succession of phytoplankton and zooplankton over a period of ten months. The result of this study is unpublished.

TABLE NO. IV-11

REPORTS AND PUBLICATIONS DEALING WITH
BIOLOGICAL OCEANOGRAPHY DATA COLLECTION PROGRAM

Report and/or Publication	Agency or Author	Remarks
Reports Containing Specific Data on Cook Inlet		
Bering Sea, Bogoslof, Simeonof, Semidi, Tuxedni, St. Lazaria, Hazy Islands, and Forrester Island, Alaska, Bulletin 1260K [28]	U. S. Geological Survey	Describes Tuxedni National Wildlife Refuge on Chisik Island in Cook Inlet.
Some Aspects of the Life History of Razor Clams *Siliqua patula* (Dixon) in Cook Inlet, Alaska [29]	Dept. of Fish & Game State of Alaska	Describes clam beds on eastern shore of Cook Inlet.
Status of Cook Inlet-Resurrection Bay Commercial Salmon Fishery, 1965 [161]	Dept. of Fish & Game State of Alaska	Describes first 6 years of state-managed salmon fishery.
Cook Inlet Area Pink Salmon Forecast Studies 1964-1966 [39]	Dept. of Fish & Game State of Alaska	Data on escapement and pre-emergent fry observations.
Forecast Research on 1968 Cook Inlet Pink Salmon Fisheries [40]	Dept. of Fish & Game State of Alaska	Relates escapement and pre-emergent fry observations to salmon forecasts.
Relation of Fecundity and Egg Length to Carapace Length in the King Crab, *Paralithodes Camtschatica* [72]	Bureau of Commercial Fisheries	Studies of king crab at Kasitsna Bay, Cook Inlet.
Surface-to-Bottom Pot Fishing for Pandalid Shrimp [11]	Bureau of Commercial Fisheries	Baited shrimp pots studied as method of shrimping Kachemak Bay, Cook Inlet, Alaska.
Alaska Fisheries 1967 Commercial Operators [2]	Dept. of Fish & Game State of Alaska	Contains statistics on commercial fishing processors and canneries in Cook Inlet.

TABLE No. IV-11 (Continued)

Report and/or Publication	Agency or Author	Remarks
1967 Alaska Catch and Production [3]	Dept. of Fish & Game State of Alaska	Statistics on types and values of fisheries harvest in Cook Inlet.

References Containing General Information on Study Area

[17, 23, 41, 55, 145, 147, 164, 167, 178]

Texts or Publications Relevant to Subject

[5, 28, 50, 51, 53, 65, 77, 84, 87, 88, 102, 146, 148, 149, 171, 176, 177, 179, 188, 202, 211]

The Bureau of Sport Fish and Wildlife has in the past, and presently in connection with studies of migratory flights of birds in the Pacific Flyway, been conducting population studies of birds over much of the State of Alaska. The shores of Cook Inlet are important nesting grounds of pintail ducks and other species. The populations of these migratory birds are fairly well recorded. A segment of these birds are year round residents and little is known of the number or types that winter in Cook Inlet.

The Alaska Cooperative Wildlife Research Unit at the University of Alaska has a proposed project to determine the nesting ecology of the kittiwake sea birds of Chisik Island in Cook Inlet. The project is pending the selection of an investigator to handle the work assignment.

In summary, very little is known about the biology of Cook Inlet. Various agencies have conducted studies on certain animals and birds within the Inlet, but with the specific purposes of commercial fishing activities and migratory bird patterns. Almost nothing is known of the plankton or benthic organisms present in the Inlet waters.

Proposed Data Collection Programs

The major objectives of the proposed biological data collection program are to determine the types and populations of the various specie of flora and fauna inhabiting the Cook Inlet area, and to describe the ecological interaction of the biota. The preliminary studies conducted will survey and inventory the populations present and later studies will attempt to define the ecological significance of the Inlet waters. The major study areas are the intertidal zone and the offshore waters; however, the terrestrial component will be examined with importance given to the bird populations.

First Phase. This phase will be devoted to organization and scheduling of the proposed data collection activities.

Second Phase. Table No. IV-12 summarized the sampling activities for the second phase data collection program. Terrestrial sampling stations are located as shown in Figures No. IV-25, IV-26. It is anticipated that the terrestrial program will be conducted more on an areal sampling basis; however, the locations shown on the map are indicative of the general locations of sampling. Emphasis should be given to determining the resident bird populations; however, it is desirable to inventory the flora and fauna interacting within the estuarine environment. The sampling locations are located in the major marshlands bounding the estuary.

The intertidal zone sampling stations are located as shown on the above figures. It is desirable to monitor the proposed stations on a monthly basis; however, in the upper Inlet, ice conditions may not permit winter sampling. The major emphasis in the second year program will be to inventory the populations inhabiting the intertidal zone. These preliminary investigations will also build a backlog of data to be used in characterizing ecological changes within this shoreline tidal influenced area. Sampling will be conducted through the use of small boats and land based transportation and possibly aircraft.

The offshore sampling stations are divided into winter and summer sampling stations due to climate and ice conditions that restrict sampling in the upper Inlet during winter months. Figure No. IV-25 and IV-26 locate the summer boat stations and show the reduced sampling grid to be used in the winter sampling cruises. The offshore sampling stations have been chosen to correspond to sampling stations for the geological, and physical and chemical data collection programs. Benthic organisms will be studied at the same time that bottom sediments are collected for sediment analysis.

BIOLOGICAL DATA COLLECTION PROGRAM

(Second Phase)

Sampling Activity	Stations New	Stations Existing	Stations Total	Sampling Station Location	Frequency	Remarks
Terrestrial						
Flora	7		7	See Fig. IV-25, 26	Twice	Spring and Fall
Fauna	7		7	See Fig. IV-25, 26	Twice	Spring and Fall
Intertidal Zone	23		23	See Fig. IV-25 & IV-26	Monthly	Winter sampling carried on conditions permitting
Plankton						
Zooplankton						
Phytoplankton						
Benthos						
Macrobenthos						
Microbenthos						
Flora						
Offshore - Summer	31		31	See Fig. IV-25 & IV-26	Monthly	
Plankton						
Zooplankton						
Phytoplankton						
Bnethos						
Macrobenthos						
Microbenthos						
Flora						
Offshore - Winter	10		10	See Fig. IV-25 & IV-26	Bi-Monthly	
Plankton						
Zooplankton						
Phytoplankton						
Benthos						
Macrobenthos						
Microbenthos						
Flora						
Fish Inventories						See Special Studies

The major objectives of the study are the investigation of the following parameters.

1. Phytoplankton
   1.1 Quantitative and qualitative enumeration of phytoplankton present within the Inlet.
   1.2 Surface and vertical distribution
   1.3 Seasonal distribution
   1.4 Primary productivity

2. Zooplankton
   2.1 Quantitative and qualitative enumeration of zooplankton population present in the Inlet
   2.2 Vertical distribution
   2.3 Seasonal distribution

3. Benthic organisms - Intertidal and Subtidal
   3.1 Obtain the number and kinds of various organisms per unit are of the bottom
   3.2 Record any useful indicator species
   3.3 Record the relevant physical and chemical parameters in the benthic environment.

The selection of station location and number of stations should be realistic in terms of obtaining representative samples from all regions of the Inlet. The frequency of sampling and the number of samples collected should also be determined in the beginning stages of the investigation. It is suggested that a series of station locations be designated as follows: near the head of the Inlet above the forelands, in the middle part of the Inlet below the forelands, near the mouth of the Inlet and a few oceanic stations outside the Inlet. At each transect at least three stations should be selected, one on each side of the Inlet and one in the middle. The samples should be collected once a month with samples from the three depths - upper, middle, and lower depths. For benthic collection the same frequency of sampling can be followed except in the case of intertidal samples wherein sampling should be done during the best low tides available each month. The above schedules can be changed if and when necessary bearing in mind the data acquired should be realistic and representative.

1. Phytoplankton

Qualitative and quantitative enumeration of phytoplankton distribution in the Inlet should be made. Surface and vertical samples

should be collected from representative stations, using a large volume sampler, and then concentrated with a continuous centrifuge. Sampling depths and frequency of sampling should be determined after due consideration of physical and chemical parameters. One complete year of work should be planned to follow the changes in the dominant species of phytoplankton. Flood and ebb tide samples should be collected to relate the population communities.

Primary productivity should be estimated by the carbon-14 technique. For this purpose, water samples should be collected with a non-toxic sampler from depths with 100 percent, 50 percent, 25 percent, and 1 percent light levels determined by a submarine photometer.

2. Zooplankton

The collection of baseline data with reference to zooplankton will follow the same pattern as the phytoplankton. For quantitative estimates, zooplankton samples should be collected with a Clarke-Bumpus sampler fitted with a No. 10 mesh net and cup. For convenience in reducing the number of samples without losing much valuable information, vertical series of samples can be restricted to the surface, mid-depths, and just above bottom. Seasonal sampling schedules should be undertaken to follow the changes in the species composition with reference to time.

3. Benthic Organisms

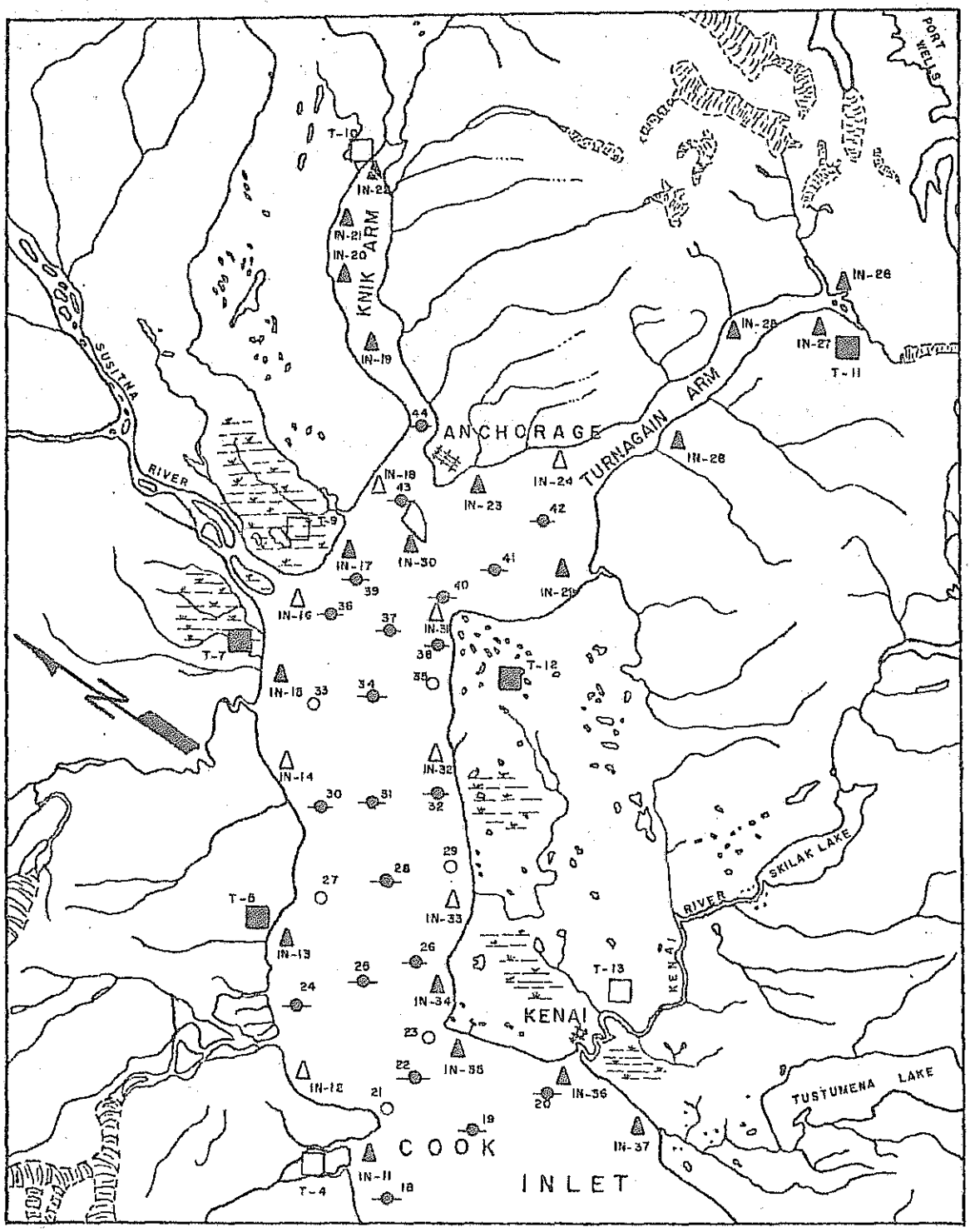
Intertidal and subtidal regions should be investigated for both flora and fauna. Quantitative samples in the intertidal zone should be obtained by hand-digging using a quadrant marker, and the nature of the resident population determined. For benthic samples, Shipek sample, Van-Veen grab or any other quantitative dredge can be used. The samples in both cases should be examined for species composition and biomass. The major emphasis should be to obtain a relevant index of indicator organisms in these zones. During the sampling procedure the physical and chemical parameters in the benthic environment should also be noted.

Fish inventories are of interest to the commercial fishing operators. The Bureau of Commercial Fisheries field research station at Kasitsna Bay has planned ecological studies on King Crab and shrimp in Kachemak Bay and the nearby waters of Cook Inlet. Fish and shellfish inventories are best conducted by specialized equipment developed for the types of fish of interest. A study could be initiated, but the need should be established and extra funds be made available before studies of this sort are planned.

Third Phase. During the third phase, the terrestrial, intertidal and offshore station network for sampling will be expanded to the total sampling network shown on the enclosed figures. With the data acquired during the pilot second year program, modifications may have to be made in the scope and locations of sampling stations. The major emphasis during the third phase will be to develop the ecological significance of the Inlet with respect to environmental changes in the geologic and physical and chemical characteristics of the estuarine waters.

Fourth Phase. The sampling programs during the fourth phase will be used to reinforce results of the previous year's sampling. This time will also be used to conclude laboratory counts and specie identification of samples taken during previous cruises. It is extremely difficult to predict actual sampling activities at this time as the results of the pilot studies will be the major determining factor in the procedures followed in the third and fourth phases.

FIGURE IV-25



△ PROPOSED AND ▲ FIRST SAMPLING YEAR BIOLOGIC STATION

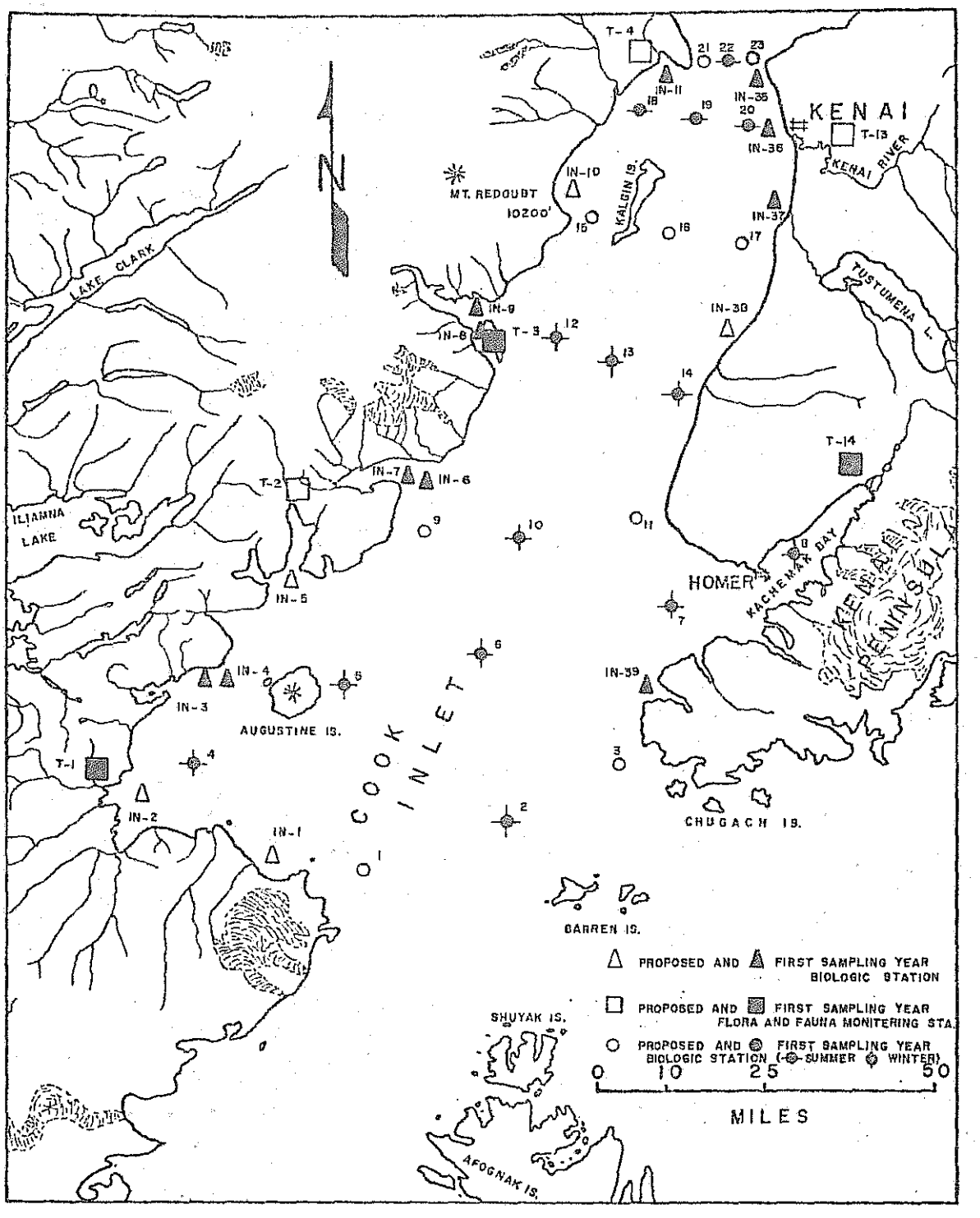
□ PROPOSED AND ■ FIRST SAMPLING YEAR FLORA AND FAUNA MONITERING STATION

○ PROPOSED AND ● FIRST SAMPLING YEAR BIOLOGIC STATION (-⊖-SUMMER ⊕ WINTER)

0 5 10 20
MILES

LOCATION OF PROPOSED BIOLOGICAL DATA COLLECTION STATIONS, UPPER COOK INLET

FIGURE IV-26



LOCATION OF PROPOSED BIOLOGICAL DATA COLLECTION STATIONS, LOWER COOK INLET

WASTE DISCHARGE INVENTORY

Introduction

Environmental change is characteristic of nature, and Cook Inlet would change under the influence of weather, glaciers, oceanic factors and many other pressures that make up the diverse natural environment even if the Inlet area were never inhabited by man. Population pressures and the development and utilization of natural resources in the Cook Inlet area can have the effect of increasing the rate of these environmental changes. Perhaps the greatest effect on the estuarine environment is caused by waste discharges from industry and municipalities. These discharges affect the quality of the water and cause changes in the ecological balance within the estuarine environment. Also the aesthetic value and potential uses of the water for consumption and industrial use are changed to a degree. Any investigation to describe the quality of water within the Cook Inlet estuary and to investigate the factors affecting the complex chemical, physical, and biological systems must monitor and describe the wastes entering the estuarine environment.

The Cook Inlet area is, to a large degree, still in a relatively unpolluted state, in the traditional sense of the word "pollution." However, other naturally occurring phenomena restrict certain sections of the estuary from complete utilization by the biota of the estuary and from man. The wastes now entering the estuarine waters are from Anchorage and other much smaller communities on the east side of the Inlet. Several refineries and petrochemical companies have been constructed near Kenai, and one company is expected to be discharging effluent to the Inlet very soon. The other source of waste discharges is from commercial fish canneries and shellfish processing operations located on the shores of Cook Inlet. Petroleum discharges to the Inlet through spills and accidental breaks in pipelines on the floor of the Inlet can affect the water quality. There is a possibility that naturally occurring oil seeps from geological formations contribute petroleum substances to the Inlet waters. It is the fact that waste discharges can affect the biota and the utilization of the Inlet waters that this report is being prepared. Therefore, the need to describe, and maintain an inventory of waste discharges becomes important.

An inventory of existing major waste discharges and oil spills is located in the appendix of this report and will be described in the following section on existing studies and data. Also several reports relating to investigations on the effect of waste discharges on Cook Inlet are listed.

Data Need and Requirements

The characteristics of waste discharges that should be monitored are: (1) the location, quantity, and variations in flow rates, (2) the physical and chemical makeup of the waste, and (3) the diffusion characteristics of the waste in Cook Inlet. An up-to-date inventory of all wastes entering the Inlet should be maintained and chemical and flow characteristics as well as the toxicity of the waste to estuarine animals should be determined. Toxicity studies can be conducted in situ or in laboratories and both should be conducted. In situ studies are described in the previous section on Biological Data Collection Programs under investigations to determine indicator organisms and monitoring population changes. Table No. IV-13 lists the desirable characteristics that should be obtained from monitoring the waste discharges.

Wastes discharged into an estuarine environment may have the effect of stimulating the productivity of the biological system. Nutrient requirements may be greater than the amount present and addition of agricultural or domestic wastes may add a sufficient amount so that algal growth is stimulated. In some cases this increase in the population of a primary segment of the food chain can stimulate growth in commercially valuable species. The reverse, or the degradation of an estuary has more often been the case, however, and documentation of the problems is presented in many references.

As Cook Inlet develops, many varied types of industries, mining and agriculture will be present in the drainage basin, each with a peculiar type of waste effluent. Each waste type has different characteristics and a different effect on the estuarine environment-industrial wastes may have toxic effects on organisms; mining activities may contribute sediments to the Inlet resulting in the covering of the benthic biota; and agricultural activities may contribute nutrients from fertilizer applications to the land with the resulting surface or subsurface runoff carrying a portion of these fertilizer components to the Inlet. Domestic wastes will increase as Anchorage and the Kenai Peninsula communities expand to meet the needs of the expanding resource utilization. Each of the wastes from the above activities require different techniques in monitoring and characterization.

At the present, an inventory should document the locations and primary characteristics of the waste discharges. As the Inlet environment is described in more detail through the proposed data collection programs, the emphasis will shift to determining the changes in the environment due to inputs to the Inlet. In the future as water quality description investigations evolve into total water resource management programs, emphasis will be placed on a detailed waste inventory and the specific character of each discharge will have to be described.

TABLE NO. IV-13

PRELIMINARY INFORMATION NEEDED FOR WASTE DISCHARGE CHARACTERIZATION

(1) Location of Waste Outfall and Outfall Diffusion Characteristics

(2) Flow Rate

(3) Variation in flow throughout day, month and year

(4) Physical characteristics

- a. Temperature
- b. Suspended Solids
- c. Dissolved Solids
- d. Dissolved Oxygen

(5) Chemical Characteristics

- a. BOD
- b. COD
- c. Nitrogen
- d. Phosphorous
- e. Total carbon
- f. pH
- g. Toxic substances
- h. Mineral analysis

Review of Existing Data and Studies

Table No. IV-14 lists reports dealing specifically to waste discharges and studies conducted on Cook Inlet. In addition, references are made by number to the bibliography for information that has a bearing on the water quality of Cook Inlet affected by wastes and to texts that provide information and background material on analyses, ecological influences and on treatment of sewage and industrial wastes.

The inventory contained in the appendix was taken from a report prepared for the Alaska State Department of Health and Welfare and dealt with the effects of the March, 1964 earthquake on the water and sewer systems in the earthquake-affected area. Emphasis was placed on the water supply systems and the characterisitcs of the water supply. The majority of sewerage systems found within the Cook Inlet basin are subsurface disposal through septic tank or seepage pit systems. Anchorage and a few other communities have waste outfalls directly to Cook Inlet without treatment. The commercial fishing facilities discharge cannery and shellfish processing wastes directly to Cook Inlet without treatment. The inventory is incomplete in characterizing the constituents and amount of waste but is complete in locating and listing the population size served by the water supply or sewerage system.

The Alaska Department of Health and Welfare in adopting the Water Quality Standards is requiring all municipalities with populations of 500 or more to provide sewage treatment by 1972 with primary treatment the minimum acceptable level of treatment. Military bases around Anchorage are to be included with the Anchorage Sewage Treatment facilities. Data is included in the appendix showing the communities affected.

Commercial fishing canneries and processors operate intermittently throughout the fishing season. The total amount of waste discharged to Cook Inlet in 1967 was approximately 5,630,500 lbs. Appendix B lists active 1967 processors and also processors filing an intent to operate in Cook Inlet in 1968.

Two investigations have been conducted in Cook Inlet relating specifically to waste discharges to the Inlet waters. The Collier Carbon and Chemical Company is an ammonia and urea manufacturing plant

TABLE NO. IV-14

REPORTS DEALING WITH WASTE DISCHARGES

Report	Agency or Author	Remarks
The Pollution of the Waters of Knik Arm [180]	Dept. of Health & Welfare State of Alaska	Information on Anchorage effluent outfall locations.
A Report on Water and Sewerage Facilities at Public and Semi-Public Places [26]	Dept. of Health & Welfare State of Alaska	Inventory of all water and sewerage facilities in Cook Inlet area.
Public Hearing Report Regarding a Waste Discharge Permit for Collier Carbon and Chemical Corporation, Kenai, Alaska [159]	Dept. of Health & Welfare State of Alaska	Public hearing report on discharge of ammonia into Cook Inlet.
Oceanography of Cook Inlet with Special reference to the Effluent from the Collier Carbon and Chemical Plant [164]	Institute of Marine Science	Determination of diffusion of ammonia effluent into Cook Inlet.
Publications Containing General Information on the Study Area [115, 144]		
Texts and Publications Relating to the Subject [29, 56, 60, 87, 94, 97, 127, 133, 135, 149, 151, 175]		

located at Nikiski on the east side of Cook Inlet. The waste discharge from the manufacturing processes will have concentrations of ammonia and it was proposed to release this ammonia to Cook Inlet through a diffuser outfall at the company's dock, one quarter mile from shore. A temporary permit to release these wastes has been granted to the firm by the State Department of Health and Welfare, based on results of public hearings and a preliminary investigation conducted by the Institute of Marine Science on diffusion characteristics of Cook Inlet at the location of the outfall. Results of the Institute of Marine Science investigations revealed that concentrations of ammonia at a short distance away from the outfall would be very low.

Monitoring of the Inlet waters for background ammonia concentrations is now being carried out and after the plant starts up sampling will be conducted to determine the ammonia build-up in the Inlet waters. The reports relating to the public hearings and diffusion characteristics are listed in the table of reports and the bibliography.

The City of Anchorage and the surrounding Borough are in the process of constructing a sewerage system which will include sewers, a primary treatment plant and a submarine outfall. The oceanographic studies as well as the design for the sewers, treatment plant and outfall are described in a report entitled "Greater Anchorage Sewerage Study for the Greater Anchorage Area Borough." [184]

In summary, the necessary data for a complete and up-to-date waste inventory are lacking as far as waste flows and characteristics; however, the locations and identity of the source of the effluents are well documented. The two major sources of waste, the Anchorage area and the petrochemical manufacturing area at Nikiski, have had some effluent characterization and oceanographic studies conducted in the vicinity of the outfalls. There is little knowledge concerning the amounts, character, and effect of canneries and shellfish processor wastes on the Inlet waters.

Proposed Waste Inventory Program

Monitoring waste discharges to Cook Inlet will not be divided into separate yearly programs. The total program will be devoted to determining the characteristics of waste discharges from municipalities or industries of significant size with discharges draining to surface water courses entering Cook Inlet or discharging directly to the Inlet. The monitoring program should begin during the second phase of the previously described data collection programs and should be updated as new communities or industries are established in the Cook Inlet area.

The following are the principal waste discharges to be monitored:

Communities

Anchorage
Homer
Kenai
Palmer
Seldovia

Oil Industry

Offshore Facilities
- Shell Oil
- Pan American Petroleum
- Mobil Oil
- Union Oil

Onshore Facilities
- Standard Oil Refinery
- Shell Oil Co.
- Phillips Natural Gas Liquification Plant

Petrochemical

Collier Carbon and Chemical Co.

Sea Food Processors (Located outside of municipal sewerage systems)

Location Beluga River
- Clam Gulch
- Cohoe
- Kalifonski Beach
- Kasilof
- Kasitsna Bay
- Ninilchik
- Snug Harbor

Military Installations

Wildwood Air Force Station

Miscellaneous

Name	Location
State of Alaska Division of Aviation	Anchorage
Diamond Jims	Indian
Vandemere Trailer Court	Anchorage
Yeagers Service	Anchorage
Crestview Village Subdivision	Anchorage
Alaskan Seafoods	Homer
FAA Complex	Kenai
Inlet Trading Post	Homer
Mommsen Subdivision	Kenai
Scroggs Water System and Trailer Court	Homer
Wakefield Specialties	Seldovia
Water Front Bar	Homer
Supper Club	Palmer

The above-listed communities, industries and semi-public facilities discharge wastes to streams and to Cook Inlet. The information was taken from the inventory contained in the appendix. The important data to be collected at each waste discharge point are (1) location of waste outfall and basic outfall diffusion characteristics (point source or diffuser), (2) flow rate, (3) variation in flow (major discharges will be characterized throughout day, month and year), (4) physical characteristics, and (5) chemical characteristics. The specific chemical and physical parameters were described in the foregoing section "Data Needs and Requirements."

SPECIAL INVESTIGATIONS

At the present time there are three major problems of immediate concern in Cook Inlet which are caused by discharge of municipal and industrial waste.

In the eleven years since oil was discovered in the Swanson River field, oil spills have occurred at various times due to pipeline breaks and platform spills (see Appendix). The influence of these spills on the biota of the Inlet resulted in the loss of ducks and other birds feeding and resting on Inlet waters. Although no one can predict the time of occurrence of a spill, the influences of these discharges on the waters and biota within the waters should be investigated. The use of dispersants and detergents has been proposed to combat the effects of the oil and past incidents where detergents were used indicated that in some cases the detergents were more harmful to the biota than the oil [171]. It is proposed that when an oil spill occurs during the next three years, field and laboratory experiments be conducted to determine the effect of the oil and the dispersants on a controlled basis. Since oceanographic studies will be occurring in the Inlet continuously, the oceanographic research vessel will have the proper equipment on board or available to begin monitoring the spill immediately. Present hydrocarbon levels within the Inlet will be determined during the proposed physical and chemical data collection programs.

The ammonia waste to be discharged to Cook Inlet at Nikiski from the Collier Carbon and Chemical Company's ammonia and urea manufacturing facility is of concern to commercial fishermen and biologists due to the possible effect of the ammonia waste on the biota. It is proposed that intensified monitoring and sampling be conducted in the vicinity of the ammonia waste outfall during the proposed data collection programs. Attention should be given to the circulation patterns, diffusion characteristics, physical and chemical parameters and the biota within the area of influence of the outfall. These studies will be conducted during routine sampling of intertidal and offshore stations.

The discharge of raw sewage through five outfalls (Figure No. IV-27) from the City and Borough of Anchorage has an effect on the water quality and intertidal mud flats in the Anchorage area. It is proposed to conduct a pollution survey and sampling study on the offshore waters and mudflats near Anchorage at the locations shown on Figure No. IV- 28. Observations should be made throughout one complete year to determine the effects of tides and currents. As shown on Figure No. IV-28, two types of stations are indicated, 1) pollution observation stations,

and 2) observation and sampling stations. The observation stations should be inspected to determine gross pollution influences such as detritus, biological changes, and major environmental changes. These effects would be most apparent on mudflats. Sampling stations should be monitored to collect sediment samples, determining physical and chemical conditions of the water and to observe and monitor the specific biological indicator species. These pollution observation stations should be monitored on a monthly basis year round and are best visited by a helicopter or small boat.

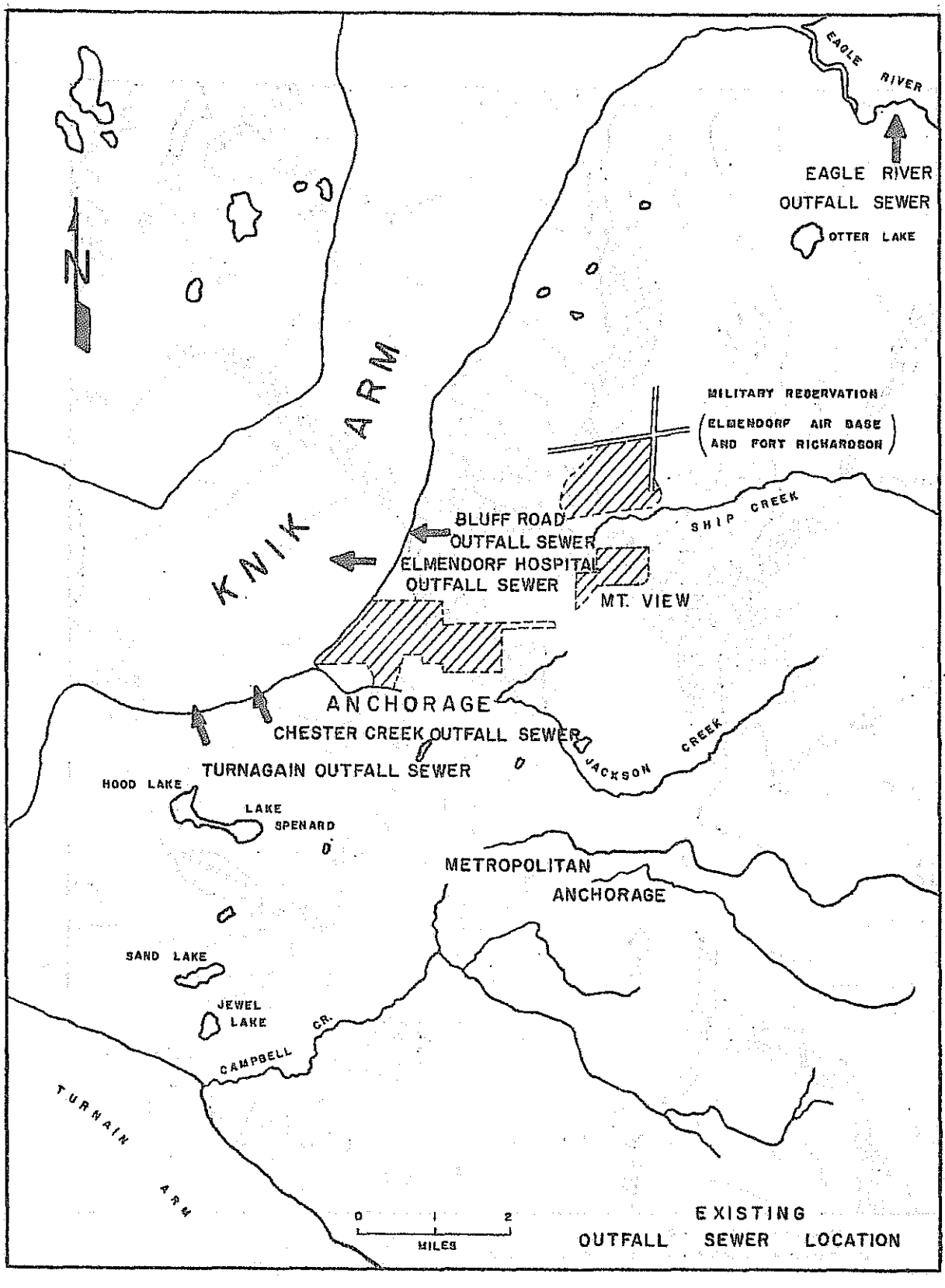
The objectives of this pollution survey should be to determine the effects on the Anchorage area environment caused by the discharge of primary sewage and the change in the envionment when the new Anchorage sewerage system is put into operation. The new sewerage system will discharge primary treated sewage through a single outfall. Federal standards recommend secondary treatment as a desirable level of treatment and measuring the changes in the area in going from raw to primary treated sewage will indicate the need to provide secondary sewage treatment. The initial observation and sampling stations should be monitored during the second year of the proposed data collection programs.

Other studies that should be considered are 1) determination of the rate of silting of Knik Arm and Turnagain Arm (sediment transport and tides and currents), 2) ice movement in Cook Inlet's upper reaches, 3) the ecological significance on the Arms of construction of highway causeways across Turnagain and Knik Arms, and 4) investigations upon the effect of petroleum products in the Kenai-Nikiski industrial area being discharged to Cook Inlet.

Two highway causeways are proposed, one across Knik Arm from Anchorage to the west shore of Knik Arm and one across Turnagain Arm. It is likely that a causeway across Turnagain Arm will be constructed first. The effect of the causeways in constricting flow in and out of the Arms is thought to directly influence the sediment deposition rates in Cook Inlet and also within the Arms. The ecology of the tidal flats and surrounding areas will also be changed and investigations should be planned to investigate the biological populations and sedimentation patterns before the proposed causeways are constructed.

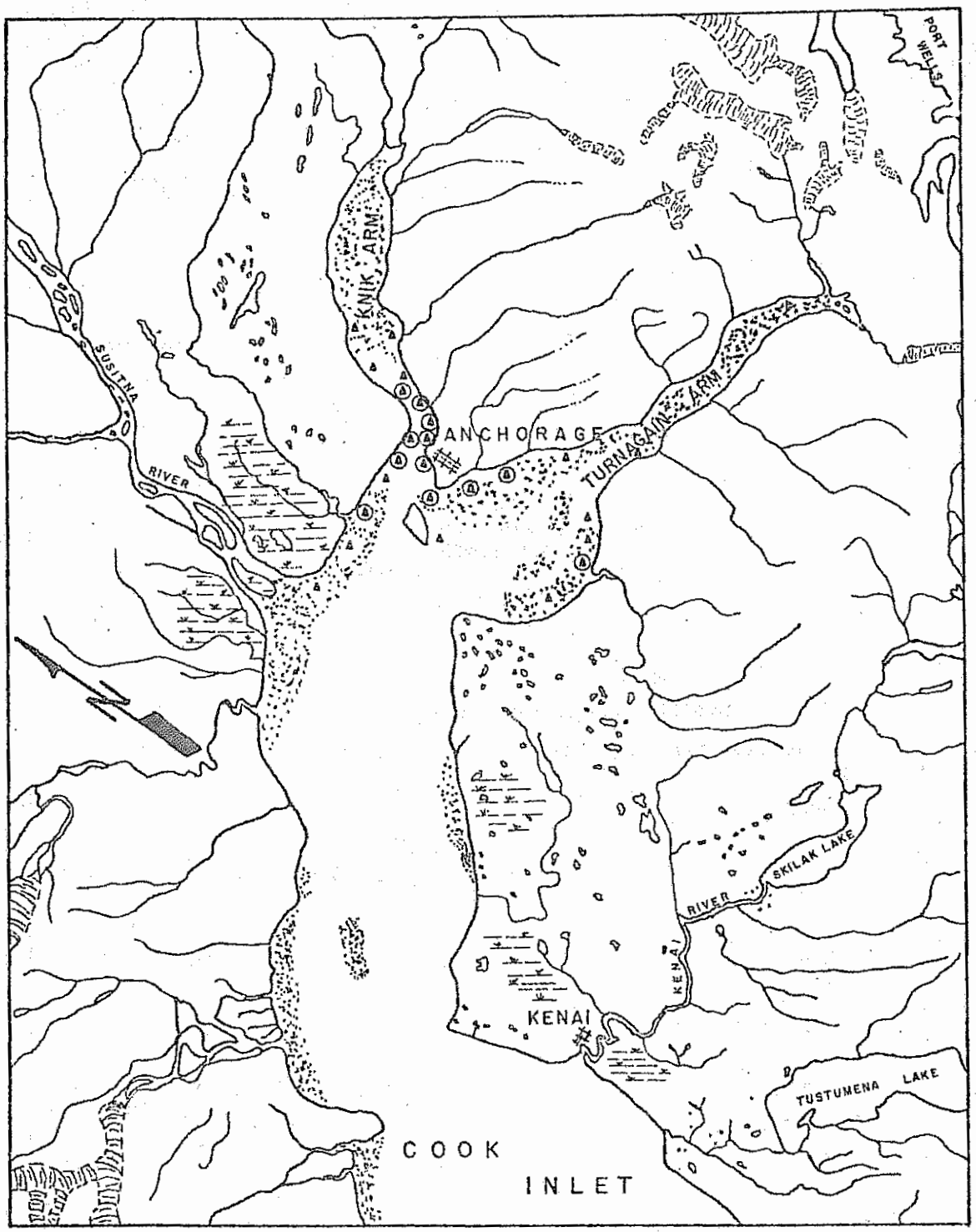
The sampling stations shown on the master station map at the end of this report will be sufficient to cover the affected areas. The stations to be used and the types of samples to be taken will be described within the chapter on program implementation.

Winter ice development in Cook Inlet hinders waterborne shipping and causes damage to docks and shops. As a practical study, investigations should be carried out to determine the effect of floe ice on docks and shoreline construction. Currents, winds, and ice formation factors should be monitored and the data derived can be used to forecast ice conditions which directly affect the ability of ships to navigate in the Inlet.



WASTE DISCHARGES FROM ANCHORAGE AREA [180]

FIGURE IV-28



▲ POLLUTION OBSERVATION
Ⓐ POLLUTION OBSERVATION AND SAMPLING STATION

0 5 10 20
MILES

PROPOSED MONITORING STATIONS ANCHORAGE
SPECIAL POLLUTION SURVEY

V. DATA MANAGEMENT

The ultimate success of any collection program will depend upon the establishment of a well planned system of data management. The primary function of this system will be to catalog and store data, and at the request of various users, retrieve the stored data in a rapid and efficient manner.

In terms of importance, the management of stored data overshadows all phases of a collection program. The collected data will have little value if it is not made available for continual use. A common fault with many data collection programs is that the original data ends up in a file cabinet and it soon becomes very difficult to obtain the data for additional use and analysis. Selected parts of the original data can usually be found in various reports, but it is generally of questionable value since 1) the data has been edited and is no longer complete, 2) it has been subjected to several error-prone procedures (e.g., typing), and 3) in order to obtain the data in a form convenient for analysis, the information will again have to be transcribed and in the process be subjected to more errors. Hence, one of the basic objectives of a data management system will be to retain the original data in a secure but easily accessible environment.

The anticipated volume of data that will be accumulated by the proposed data collection program precludes the use of simplified methods of data handling. It is expected that data will originate from four sources 1) from the proposed data collection programs, 2) from past and current collection programs, 3) from analysis of accumulated data and 4) from new data collection programs. The latter are expected to be implemented as a result of analyzing data from the various existing and proposed collection programs. For these reasons, it is recommended that a computer-based data management system be implemented and used. The purpose of this chapter is, therefore, to present and discuss in detail the activities and tasks associated with the development of a computer-based system for the management of data encompassing its storage, retrieval, and analysis.

AN OVERVIEW

Although this chapter deals with the development of a computer-based data management system, it should be recognized that systems of this type have not always been as successful as might have been hoped. While there are many reasons for these apparent failures, the primary one is lack of money to support adequate planning and development. The

fact that funds are more frequently allocated to collect and deposit data than to retrieve and analyze them tends to reinforce this concern. In addition, the scope of the proposed data collection programs suggest that the problems of data management will become critical. Therefore, it is imperative that the planning and development phases be fully supported so that a usable data management system can be developed and implemented.

Data management systems that have succeeded in overcoming the problem of handling large volumes of data and have solved the difficult problems of storage and retrieval have often created the frustrating problem of being difficult to use. The potential "outside" user is generally restricted in the choice of formats and mediums for data and quite often limited in his selections of data. In addition, his requests must go through a third party who is familiar with the use of the system. For these reasons, it is recommended that serious consideration be given to implementing a user-oriented data management system. The concept of user-oriented systems is well established in the field of engineering. For example, the COGO (COordinate GeOmetry) programs, developed at Massachusetts Institute of Technology, were designed to allow an engineer to use everyday engineering terminology in communicating with the programs.

Before describing the many phases of system development, it is appropriate to examine the complete data collection program to determine the specific role of each phase in development. The integrated roles of data collection and data management and the associated activities are illustrated in Figure 1. The activities associated with the development of the data management system include 1) formulation of management objectives and requirements; 2) planning the system, including the development of a systems group, formulating standards, and reviewing existing procedures; and 3) system design and implementation. The end product of these activities will be a data management system.

The sequence in which the various activities can proceed are also indicated in Figure No. V-1. With exception of planning, the various activities associated with both the data collection program and the data management system can be pursued independently. During the planning stage the formats of the data collection forms should be fully designed. This will minimize the possibility of problems occurring during the data processing stage. A typical problem that generally occurs is that of having to transcribe the data into a format that is acceptable to data processing operations.

Additional information dealing with a variety of topics in data processing and data analysis will be found in the references cited in Table No. V-1.

Figure No. V-1

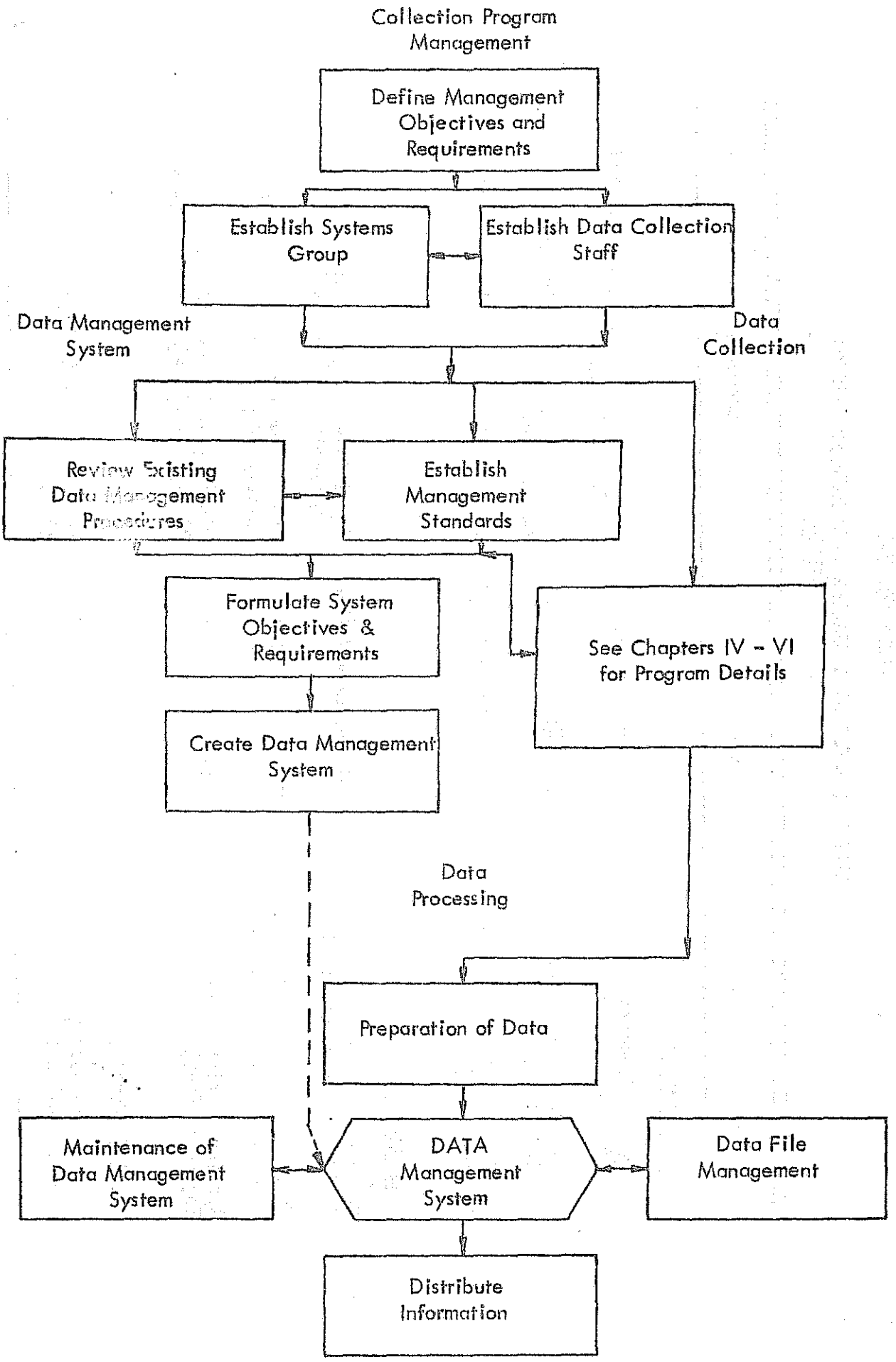

Collection Program Management
Define Management Objectives and Requirements
Establish Systems Group
Establish Data Collection Staff
Data Management System
Data Collection
Review Existing Data Management Procedures
Establish Management Standards
Formulate System Objectives & Requirements
See Chapters IV - VI for Program Details
Create Data Management System
Data Processing
Preparation of Data
Maintenance of Data Management System
DATA Management System
Data File Management
Distribute Information

TABLE NO. V-1

SELECTED REFERENCES DEALING WITH DATA PROCESSING AND DATA ANALYSIS

Title	Publisher	Comments
Data Processing		
Management Standards for Data Processing [16]	D. Van Nostrand Co.	Good presentation of standards and their development
Systems Design for Computer Applications [100]	John Wiley and Sons	Broad analysis of system design methodology
The Analysis of Information Systems [134]	John Wiley and Sons	Deals specifically with information retrieval processes
Data Analysis		
Numerical Methods and FORTRAN Programming [128]	John Wiley and Sons	Integration of analytical and programming techniques
Numerical Methods for Scientists and Engineers [69]	McGraw-Hill Book Co.	Presents methods of solving a wide variety of problems
Applied Statistics for Engineers [190]	McGraw-Hill Book Co.	Statistical theory applied Statistics for engineering problems
Other References		
Data Processing		[8, 97, 150, 170, 173]
Data Analysis		[1, 5]

PLANNING

The most critical step in the development of a data management system is planning. Without an extensive planning program, the resulting system is likely to evolve as a rigid entity, unresponsive to changing demands and, quite possibly, unable to fulfill even the initial system requirements.

The planning program will consist of three distinct operations. 1) Establishing a staff of key personnel, 2) defining specific objectives, and 3) reviewing existing data collection and management procedures and techniques.

Staff

The development of a data management system is a complex and difficult task and it is very important that the personnel responsible for the development be well trained and experienced in this area. The success of the system will, to a large extent, depend upon the selection of these personnel. They should be highly competent in the areas of system design and development and would preferably have some experience in sanitary engineering.

The proposed method of implementation indicates that a staff of three would be required to develop and maintain the data management system, and should include two experienced system designers and one experienced programmer. It should be noted that while this staff will develop the system design criteria and specifications, they will not be able to perform the actual programming work on the initial system. A much larger staff will be required to accomplish this task and it is recommended that the work be submitted to contract. The staff must, however, maintain strict control of the programming phase and supervise the project development from start to finish. In doing this they will be assured that they will have full knowledge of the system and be able to maintain the system once it is in operation.

Objectives

The objectives of the data management system will define the overall characteristics of the system. In addition, they will establish specific performance and operational requirements. It is important that a comprehensive study be made of the present and future data management needs so that a complete set of objectives is formulated.

This will minimize the possibility of having to make major changes in concept at a later date when the system is operational. This type of change is expensive and difficult to accomplish successfully.

Characteristics. System characteristics serve the purpose of defining the desired attributes which the system is to possess. Naturally these attributes are general qualities of the system rather than specific requirements, but they will be useful guides when developing specific criteria.

Examples of system characteristics are:

- Easy to use
- Easy to modify
- Reasonable response time
- Performs requested services
- Dynamic in scope

Since these characteristics are general, they create a climate of investigations. For example, the phrase "Easy to use" will raise many questions in the minds of the system designers--What constitutes a system that is easy to use? or easy for whom to use? or what is meant by easy? Such questions will bring up many important design aspects that might otherwise be overlooked. An example of this is the question "Easy for whom to use?" In answering this the system designer must first investigate the types of users who are likely to use the data management system and second, he must tailor the system so that it will meet their particular needs. And in doing this he must try to use their frame of reference and not his own.

Requirements. The specific performance and operational requirements are similar to the characteristics in that they are broad, general statements which define tasks that the system must accomplish. They do not explain how the system will do these tasks, nor do they specify any methods which the system must use. They simply state what must be done. The requirements for a data management system can be stated as follows:

1. The system must input, catalog and store data.
2. The system must maintain and update this data.

3. The system must find (retrieve) data on demand.

4. The system must perform specified analytical operations on the data.

5. The system must output the requested data in the form that the user requests.

As with the statements of characteristics, each of these requirements opens major areas of investigation. For example, the requirement that the system must "catalog" the data means that some methods must be defined that will perform this function. Since there are many methods of cataloging data, the method selected will depend upon the type of data that is to be stored. This implies that a complete investigation must be made to determine the characteristics of the data.

Review

After formulating a set of objectives, it is necessary to review existing data collection and management procedures. In doing this, two things will be accomplished; one, the review will reduce the possibility of duplicating existing operations and two, the review and study of current methods and practices will provide new ideas and concepts for use in the proposed data management system. It is quite possible that the review will cause new objectives to be specified. These objectives will define additional functional capabilities that must be implemented in the management system. Specific items that should be reviewed include existing data and data management systems.

Existing Data. The review of existing data should result in a tabulation of the data characteristics. These characteristics will include quantity, type classification and quality. Since it is expected that much of the existing data will be used, it will be necessary to plan for its inclusion in the data management system. Quantity will be an important factor which will directly affect the storage concepts used in the data management system. Type and classification will affect the method of data organization. In addition, the existing classification must be reviewed to determine that it conforms to those classifications that will be formulated in this program.

In addition to reviewing the characteristics of existing data it will be necessary to determine the data formats. If the existing formats are unacceptable, then it will be necessary to specify new formats prior to preparing the data for the data management system.

Existing Data Management Systems. The purpose of reviewing existing systems is to allow staff members to become familiar with current systems used for the management of data. This review will also present an opportunity to incorporate additional objectives and requirements as methods of other systems are reviewed.

Specific areas of investigation should include a study of the methods used to handle exceptional as well as routine tasks. If any area of system design is likely to cause problems, it is the methods of handling exceptions. For example, in a payroll program it is quite easy to calculate the amounts for a paycheck based on 40 hours of work. But the system becomes more complex when overtime, vacation, holidays, and time off are considered.

Other areas of study are the various types of program outputs. This area will generally give a good indication of how versatile the system is. In addition, there should be an in-depth analysis of the methods of inputting requests to the system. In particular, these methods should be studied in light of input methods used in other user-oriented programs such as COGO and STRESS (ICES SYSTEM PROGRAMS).

STANDARDS

The term "standards" as used in this chapter, defines an established set of criteria for use as guides and for yardsticks of measurement. As guides, standards are used to establish uniform practices and common techniques, and as yardsticks they are used to measure the performance of personnel and equipment.

There are several major reasons for the necessity of formulating standards. The most important one being self-preservation. The manager who has lost a key programmer in an organization which does not have standards will readily testify to the large costs involved in "taking over" undocumented programs. In many cases, large programs have been discarded and rewritten at a tremendous cost in manpower and loss of business. It is therefore important that standards be established so that the computer programs developed will be personnel independent.

Also, the unusual technical nature of data processing functions has, in many cases, caused a loss of management control. Without a set of standards, the manager is not in a position to judge the length of time to perform a data processing project. Further, he lacks an effective method of scheduling manpower resources. The result is complete loss of control.

There are many types of standards, each developed to serve a particular need. The most common standards found in practice are grouped in two functional types. These types are shown in Table V-2 along with major subdivisions and the benefits derived from each type. The development and use of these standards is the most important part of the entire management control function.

TABLE NO. V-2

STANDARDS FOR SYSTEM DEVELOPMENT

Type	Sub-Type	Benefits
Methods		
	System Analysis	. Economic expansion and conversion
	Programming	. Reduced personnel turnover effects
	Operation	. Improved management techniques
		. Reduction of future costs
Performance		
	Equipment	. Ability to develop realistic costs and budgets
	Personnel	. Ability to develop schedules
		. Improved management control

Methods Standards

While it is anticipated that all the standards listed in Table No. V-2 will eventually be formulated and placed in use, the development of methods standards is a most urgent requirement for the proposed data collection program. These standards will insure that a useful and functional data management system will be developed regardless of whether the work is performed by in-house personnel or by outside contractors. These standards will serve as part of the design specifications and as such will insure the sound development of the desired system. Without them, the changes of obtaining a functional data management system are practically non-existent.

As shown in Table No. V-2, methods standards are composed of standards for systems analysis, programming and operation. Each of these subtypes are standards which aid in the development of a data management system.

Systems Analysis. There are five major standards that should be developed for use in specifying the data management system requirements. These standards are important since they will insure that the desired system will be properly defined.

1. Glossary of terms. The purpose of defining terms is to avoid conflicting or confusing meanings by stating the intended meaning or meanings.

2. Data Formats. There are many types of data formats that must be considered. They include data forms for use by the data collection personnel, punch card layouts, disk and/or tape layouts and printer forms layouts and other output documents. The data collection forms should be designed for easy field use while at the same time being structured so that the data is easily transcribed to a machine-readable document. Punch card layouts should reflect standard keypunch methods in order to maintain high operator efficiency. Data formats for mass storage devices such as magnetic tapes or disks will depend on the storage and retrieval methods selected and should allow room for expansion. Printer forms layouts should meet the demands of each user with consideration being given to special services such as binding, bursting, decollating, etc. For example, if a report is to be bound in an unburst form, space should be provided at the top of each sheet so that information will not be hidden under the binding edge. Other output documents might include tapes on which specific data is written at the request of a user, the tapes being sent to the user in lieu of or in addition to printed documents.

3. Flowchart. These standards should aim at uniformity while defining the type, format, and information to be shown on flowcharts.

4. Data Specifications. There is a definite need to standardize the types of data to be managed by the system. The methods of identification and classification must be thoroughly investigated and a standard selected. The data collection program will be generating data of all types and from widely varying geograhic locations. The problem of identification is of major importance--its solution will have lasting effects on the data management system.

5. System Definition. The most difficult task undertaken in systems analysis is to select a standard method of defining a system. The method selected should require that the system definition be structured to allow modular development. The definition should specify the requirements for a Job Specification Manual. This manual will contain the job requirements and methods and will be used by the programmers.

Programming. The major areas of the programming function that require standards are logic analysis, coding methods, programming rules, program checking and testing and documentation. The most important reason for these programming standards is to insure that all programmers will produce a product that is understandable to other programmers. In addition, these standards will result in better programs that will run more efficiently, be easy to test, and most important, will be easy to change.

1. Logic analysis. The programmer will take the system flow chart prepared by the system analyst and make detailed flowcharts for each program used in the system. This standard will consist of rules to follow which will specify the formats, methods, coding schemes and desired complexity. There will also be an explanation of the reasons for each rule so that the programmer will understand the purpose of each restriction.

2. Coding Methods. These standards will define the programming language to be used and place restrictions on the use of other languages. For example, "All programs shall be written in FORTRAN except in cases where FORTRAN cannot be used. Basic assembly language may then be used, only with the approval of the project manager." The use of comments in the program listing will be explained and specific requirements will be formulated. Variable names, labels and/or statement numbers must be selected with specific purposes in mind rather than by an arbitrary whim of a programmer. For example, if a variable represents the sum of a set of numbers, the variable names should reflect this, e.g., SUM rather than some unrelated word such as DOG.

3. Programming Rules. Standards for this phase of programming will state specific housekeeping tasks that a programmer must perform. For example, the printer should be restored to the top of page condition under program condition under program control rather than rely on an operator. In addition, the rules will be imposed which account for particular restrictions of the computer and related equipment and to special features of the language compiler or translator to be used. For example, it would not be good practice to allow the use of a special language operation if this operation was not available on other machines of the same general size.

4. Program Checking and Testing. Specific methods should be formulated to insure that programs will be checked and tested with a minimum of expense and a maximum of effectiveness. Programs should be "desk checked" prior to running on the computer. Not only will many errors be detected, but it will insure that blocks of logic have not been inadvertently left out. These standards should be specific as to the procedure that must be followed. A complete set of testing procedures should also be developed. These procedures will be structured to 1) test each block of the program, 2) test the complete system and 3) test in a manner in which exceptions or special conditions are imposed for evaluation. It is not enough to determine that the system will function on expected types of data, it must be able to handle the unexpected also. This may involve simple rejection of 'bad' data.

5. Documentation. The importance and necessity of good documentation is generally underestimated. This is due to the fact that a program will run whether it is documented or not and this tends to give management a false sense of security. The truth is that an undocumented program is doomed to failure. It is an accepted fact that sooner or later every program will display a "bug" that has not occurred before. Effecting a correction will be very difficult, if not impossible, if the original programmers have since changed jobs. Since personnel turnover rates in such facilities are quite high, ranging up to 50 percent, it is extremely important that documentation be insisted upon. It is also reasonable to expect that changes will be made to a program package to expand its scope. The costs of changing an undocumented program can be ten times as great as for changing a documented program. In addition, it can be expected that sooner or later the programs will be converted to a more advanced computer. The absence of complete and up-to-date documentation will make this task very difficult and costly.

   The programs which will comprise the data management system should have the following documents as part of the system documentation:

   a. A program information manual

   b. A program operational manual

   c. A program user's manual.

   The program information manual should contain two sections. The first will be comprised of a system abstract, a system flowchart and a complete layout of all record formats. The second section will consist of detailed information about each program. This information will include variable summary sheets,

flowcharts, program listings, test data listings and output and machine setup sheets.

The program operating manual will contain the instructions necessary to run the programs. All operator functions will be defined in this manual. Machine setup procedures, data deck configuration, and a list of program halts with detailed operator intervention will be explained. Also this manual should tell the operator what should be done in case of an unexpected situation. For example, "The operator will initiate a core dump from core address 1F20 (HEX) to 2FE6 (HEX) should a run ever exceed 15 minutes." The program user's manual will be used by various people who wish to obtain information from the system. This will be their only means of communicating their requests to the data management systems and the manual should be written with this in mind. In addition to explaining what can be done, it should also explain what cannot be done so that a user will be aware of what he can and can't do. It would be unreasonable to expect the system to be capable of performing all conceivable functions; therefore, practical limitations will be imposed and these limitations should be documented.

Operation. It is anticipated that the data collection program will not require development of a separate computer installation. The use of computers that are currently in operation such as at the University of Alaska is expected to be more than adequate. Should the situation arise that indicates that exclusive use of a computer is required, then it will be necessary at that time to formulate standards of operation.

Performance Standards

These standards are based on a need to be able to measure the effectiveness of equipment and personnel. If standards of performance are not formulated, it will be very difficult to make judgments concerning the expected costs of anticipated projects or to evaluate personnel effectively.

For the proposed data collection program, an extensive set of equipment and personnel performance standards may not be required. Since in-house computer facilities are not anticipated at this time, the development of extensive equipment standards is not justified. There should, however, be a set developed that will allow evaluation of the equipment that is to be used with respect to operation and performance of the data management system. The formulation of extensive standards for personnel performance may not be required since the size of the staff is expected to be quite small. Naturally, there should

be at least a skeleton set of standards so that management will not be deprived of a frame of reference when evaluating performance reports or project schedules.

SYSTEM DESIGN

The developments in the previous sections of this chapter have established the criteria, methods and objectives for the data management system. The purpose of developing this information has been to obtain a set of guidelines for use in the actual design of the system.

Functionally, the data management system must process various types of data from a variety of media and formats, meet a wide range of user demands, and maintain security of the stored data. This information must be fully established before the system is formulated. Since this information will determine the system design philosophy, it is extremely important that all areas be given full consideration. In addition, preparation of a set of design specifications that will insure the desired system is implemented.

Data Processing

The function of data processing is to perform specified operations on data that is input to the system. These operations include reading the data, determining what type of data has been read and then storing the data in a specified manner. These functions depend upon knowing specific information about the data types, formats, input media, indexing procedures, and file organizational methods.

Data Types. There are two major data type classifications: "hard" data and "soft" data. "Hard" data are those types of information that are in numerical form such as measurements or observations. The data collection programs will generate hard data from field work. Examples are temperatures, salinity, tidal currents and precipitation. Data that exists in such forms as written documentaries, drawings and plans are classified as "soft" data. In connection with the data collection program, "soft" data will include maps, plans and drawings, and reports from previous studies. The extent to which "soft" data are included in the data management system should be given careful consideration since management of "soft" data can be very complex and hence expensive to implement as part of the system. The ultimate use of the stored data will determine the relative emphasis to be placed on each data type.

Data Formats. The formats of the incoming data will vary with each collection program and will change from time to time to meet new or different field conditions. In addition, data may originate from other sources, such as another government agency with formats that likely will differ from those of this program. Since the data management system will be reading this data, it must know the exact formal specifications for a particular set of data. It is important then, that a flexible method of changing formats be incorporated into the systems program.

Data Input Media. There are several types of input media that are likely to be used at one time or another. They include cards, paper tape, magnetic tape, magnetic disks and possible source documents via an optical code reader. This is particularly true when data is obtained from an outside source. In this case, the data may be available only in one medium such as magnetic tape. Therefore, the data management system must be designed to accept on demand data from various input devices.

Data Storage. The problem of data storage os not, in itself, a difficult one, providing adequate storage facilities are available. The major problem is efficient retrieval of stored information. Efficient retrieval is obtained only if the data is properly indexed and organized. This problem is similar to those associated with a filing cabinet. It is easy to place information in the drawers, but being able to find it may seem impossible if the files are not properly organized. Therefore, it is very important that proper index and cataloging procedures be established. Another phase of data storage to be considered is that of file organization. The system response time, i.e., the time required to complete an assigned task, will depend heavily upon the data organization. For example, if the data is stored by sampling location, then it will take longer to retrieve a given parameter, such as temperature, from each location than it would if the data were stored by parameter. Under these conditions, it would be better to store the data by parameter if it were determined that most of the requests would be for parameter data. Hence, there must be a major planning effort to determine the best organizational method to use.

User Demands

The data management system owes its existence to the demands of users for information, since without these demands, there would be no need for the system. It is important then that the system be designed to allow convenient use and be designed to provide the required service. This service will include being able to output the data in a format easily specified by the user, perform a wide variety of analytical

tasks, and respond to the user demands in a reasonable length of time.

Analysis. There are many standard analytical procedures that will be used in connection with the data collection program. Finding the mean and standard deviation of a data set is but one example of the many procedures that will be required. The user should be provided with a means of obtaining data and having it analyzed easily in a specified manner. A set of standard procedures that the data management system must perform should be included in the initial system. Further, the system should be structured so that additional procedures can be incorporated as their need demands.

Report Formats. In addition to retrieving and analyzing data, the data management system must provide the information to the user in a format that is easily read and understood. In this regard, two methods should be incorporated into the system. First, there should be a wide variety of standard output formats which the user can select for his particular application, and, second, the system should be designed to select applicable formats when the user does not specify a particular type. Also, the usefulness of the system will be greatly enhanced if the system will provide varous forms of plotted output upon request. The old saying "A picture is worth a thousand words," is particularly true when dealing with "hard" data. A plot of a particular relationship between parameters will yield a visual display of the relationship. This visual information will add to the clarity and depth of the reports, making them easier to use and understand.

Response Time. Practical limits should be established concerning the response time that will be required of the system. These limits will affect the type of equipment that will be required, directly. For example, if the data management functions were done by hand, no equipment would be required but the response time would be measured in days or weeks. If, however, the response time were limited to no more than a few seconds, an elaborate and very expensive computer complex would be required. A reasonable approach would be to set the limits to meet practical requirements. These requirements will depend upon the volume of user requests and the time requirements of the user. Therefore, a thorough study should be made to determine the expected usage rates of the system and the time limits required by the various users. This study will establish information that is critical to the system design and to equipment selection.

Data Maintenance. Since a great deal of time and money was spent in gathering information, it is important that a set of data security and backup procedures be developed to protect the data. These procedures should protect the data from accidental destruction by fire, flood, etc., and from unintentional destruction through programming

errors. Such provision as "read only" mode when using data files to obtain data for users will help protect stored data. Also, by restricting data file manipulation to a few special areas of the system it is less likely that program error will go undetected during testing. In addition to placing restrictions on the system to protect the data, it is also necessary to have a well organized backup procedure. For example, duplicate sets of data could be stored in different locations to minimize the possibility of data being lost or destroyed.

Equipment Requirements

Upon completion of the preceding activities, a list should be compiled which would contain quantitative information concerning the data to be processed. This information will be used to establish minimum mass storage requirements. These requirements will determine equipment requirements for the input-output devices and for the mass storage devices.

Also at this time, it will be necessary to select modular restraints on the data management programs. For example, one of these restrictions might state, "The programs shall be structured in Core load modules of 64,000 Bytes (8 bits/Byte)." This will prevent the problems that occur when the contractor, without any restrictions, designs the system to run on a very large machine and then tries to segment the programs so that they will run on a smaller machine. The exact requirements will, of course, depend upon the results of an equipment availability investigation.

Specifications

The last task to be undertaken prior to structuring and programming the data management system is to prepare a set of specifications. The importance of these specifications is difficult to overemphasize. The fact that the importance of specifications was underestimated has caused the total failure of many expensive systems. The reasons for this may, in part, be contributed to the technical nature of the work. It is, however, difficult to understand why management will require a detailed set of plans and specifications for most construction projects, even those costing only a few thousand dollars, while at the same time contract for a system design costing tens or hundreds of thousands of dollars and neglect to provide a set of comprehensive specifications.

The specifications for the data management system should be written to accomplish two tasks. They are:

1. To define the owner-contractor relationship.

2. To define the contract requirements.

The relationships between the owner and the contractor are no different for this project than for any other. Therefore, this section of the specifications will be similar to the general provisions section of standard contracts. It will include a statement of the work to be performed, sequence and progress requirements, and guarantees of workmanship and materials. In addition, references to materials and personnel furnished by the owner will be made. In general, this section will define practices that apply to the total project while specific items are referenced in the technical section of the specifications.

The second section of the specifications, the System Job Manual, will contain the detailed instructions necessary to obtain the desired quality and service in the finished product. This manual will be composed of two major sections, each containing specific requirements which the contractor must meet. These sections are:

1. System specifications.

2. Programming and Documentation Standards.

The system specifications will be a detailed list of the functions which the system must perform. The specific requirements of the system will be defined. These will include such items as mass storage requirements, input-output methodology, and equipment specifications. This section will also contain the system flowcharts which will present a pictorial view of the major system functions.

The programming and documentation standards will detail the requirements in these areas. These standards will be similar to those outlined in the "Standards" section of this chapter. Their purpose is to insure that the finished product will be in a well-defined state in order that future changes and routine maintenance can proceed at minimum cost to the owner.

IMPLEMENTATION

The recommended approach for the development of a data management system is based on current knowledge of the anticipated scope of the project. Naturally, if the project scope were to increase significantly, an appropriate change in the implementation approach would be in order.

The recommended approach is to divide the work into two areas--that which will be done in-house, and that which will be contracted to an outside organization. Recommending that a portion of the work be contracted is based on consideration of long-range management objectives and staff requirements. Staff requirements indicate that three staff members will be able to perform all phases of the work, except the actual construction of the system. That phase will require many more people if the system is to become operational within the required period of time. Therefore, to avoid the problems of over-staffing, it is necessary that a major portion of work be submitted to contract. Data management objectived dictate that there must be in-house management and technical control of the data systems development and maintenance. Hence, the requirement that the staff be at least large enough to insure the control. This then rules out the possibility of submitting the complete system to contract.

Phase 1 - Planning and Design

This phase will consist of five activities. The activities and the results of each are shown in Table No. V-3. The three major activities will be to review existing data collection and management programs, formulate a standards manual and establish the requirements and specifications for the data management system. The end result of this phase will be a job manual for the system.

Phase 2 - Consultant's Review

The purpose of this activity is to obtain a comprehensive review of the job manual. The Consultant will review the job manual to determine that all phases of design have been included. He will also evaluate the system specifications to insure that the objectives of the program will be fulfilled by the contractor. The result will be a finalized job manual ready to submit for bids (see Table No. V-4).

Phase 3 - Design by Contractor

The contractor in this case can be outside private firms or the University of Alaska computer center. Following the consultant's review in Phase 2, the invitations to bid will be submitted. Upon reviewing bid proposals and awarding a contract, Phase 3 will begin. This phase will consist of several reviews

TABLE NO. V-3

Implementation - Phase 1 - PLANNING AND DESIGN

Activity	Manpower Man-Days	Output
1	20	A complete list of data management objectives.
2	15	Staff: Two systems analysts-programmers, one programmer.
3	150	Review report: Existing data collection and management programs.
4	200	Standards manual.
5	175	Data management system requirements and project specifications.
Total	560	Job Manual ready for review

by the planning staff (see Table No. V-5). These reviews are a necessary part of the data management system development as they will insure that the system is being developed as specified. Further,

TABLE NO. V-4

Implementation - Phase 2 - CONSULTANT'S REVIEW

Activity	Manpower Man-Days	Output
1	60	Job manual ready to submit for bids. (All work done in Phase 1 will be reviewed by a data processing consultant for content, intent, and completeness).

these reviews will allow changes to be made to the system during its development at relatively small additional costs, rather than trying to make these changes after the system is operational.

TABLE NO. V-5

Implementation - Phase 3 - DESIGN BY CONTRACTOR

Activity	Manpower Man-Days	Output
1	120	System Flowchart for Review
2	400	Complete System Coding for Review
3	50	Test Results for Review
4	300	Three Manuals: System, Operation and User, for Review
5	30	Complete System for Review and Acceptance

Phase 4 - System Maintenance

The final stage of development will be to take over maintenance of the system. It is expected that correction of errors in the system will not require a great deal of time. The major share of maintenance time will be devoted to making changes in the system. These changes include adding new analysis routines, incorporating new management concepts and expanding the system to meet new management objectives.

TABLE NO. V-6

Implementation - Phase 4 - SYSTEM MAINTENANCE

Activity	Manpower	Output
1	60 Man-Days	Maintenance Procedure Manual
2	1 Man Yr /Yr	Maintained System - Continuous

VI. PROGRAM IMPLEMENTATION

INTRODUCTION

The previous sections of this report have described the study area and have presented the data collection programs needed to characterize the existing environment of Cook Inlet and the facilities needed to store and analyze the larger quantities of data which results from such programs.

The purpose of this chapter is to present a framework by which the overall estuarine characterization program can be implemented and managed. A plan showing the scheduling of the proposed program has been developed, the existing organizations having an interest in, and also carrying on investigations in Cook Inlet are discussed, a estuarine study program management structure will be shown; and the costs and financing of the individual activities and overall program will be developed and presented.

The program schedule and costs described first in the following pages is considered to be the optimum program which will yield all the desired results in the shortest time and, at the minimum overall expense to achieve the total program objectives. After examination of results of estuarine investigations in the other states in the past few years, the authors feel that it is most desirable to conduct the Cook Inlet investigation as a four phase coordinated study. Political and economic realities with the State of Alaska, on the otherhand, would place confines on the achieving of program objectives in a four year or four phase study. If the confines, political or economically, become too restraining, the program described would fail.

The latter section of this chapter presents an alternative solution to acquiring baseline data on Cook Inlet. Priorities are placed upon the various proposed programs and costs are then attached for each of the separated studies. In this way smaller amounts of funds may be budgeted to achieve immediate goals with less pressing needs subordinated to the future. This latter approach is self-defeating over the long run as much greater expense is encountered in repeating certain parts of investigations, in storage and retrieval of data, and in lack of coordinated program management.

OPTIMUM PROGRAM SCHEDULE AND CONTROL

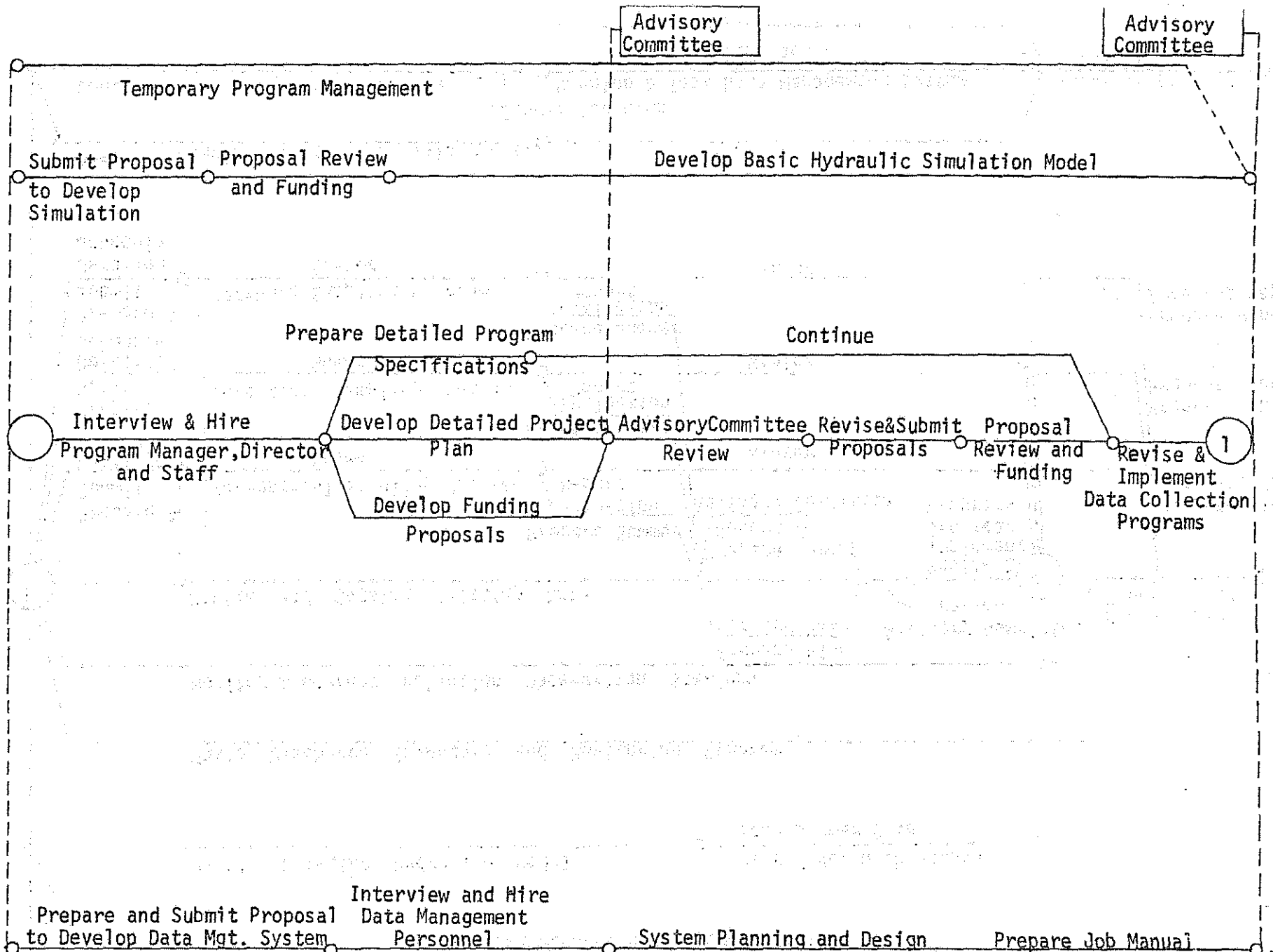
Activity Scheduling

The activity charts shown on the following pages (Figure No. VI-1, VI-4) are a schedule of the optimum sequence of tasks that must be followed if the stated objectives of the report are to be met economically. Ideally, the program will take four years - one year to plan and organize the data collection programs and hire the necessary personnel and the next three years to carry out the data collection programs. The activity chart is characterized by five control points - one at the beginning of the program and one at the end of each year. The activities within any one year, although the horizontal scale roughly corresponds to the length of time given to any activity, are not held to a definite schedule. Program planning and scheduling activities will be discussed in the following sections. The "years" could be expanded into phases of more than one year as long as program coordination is maintained.

Component Task Description

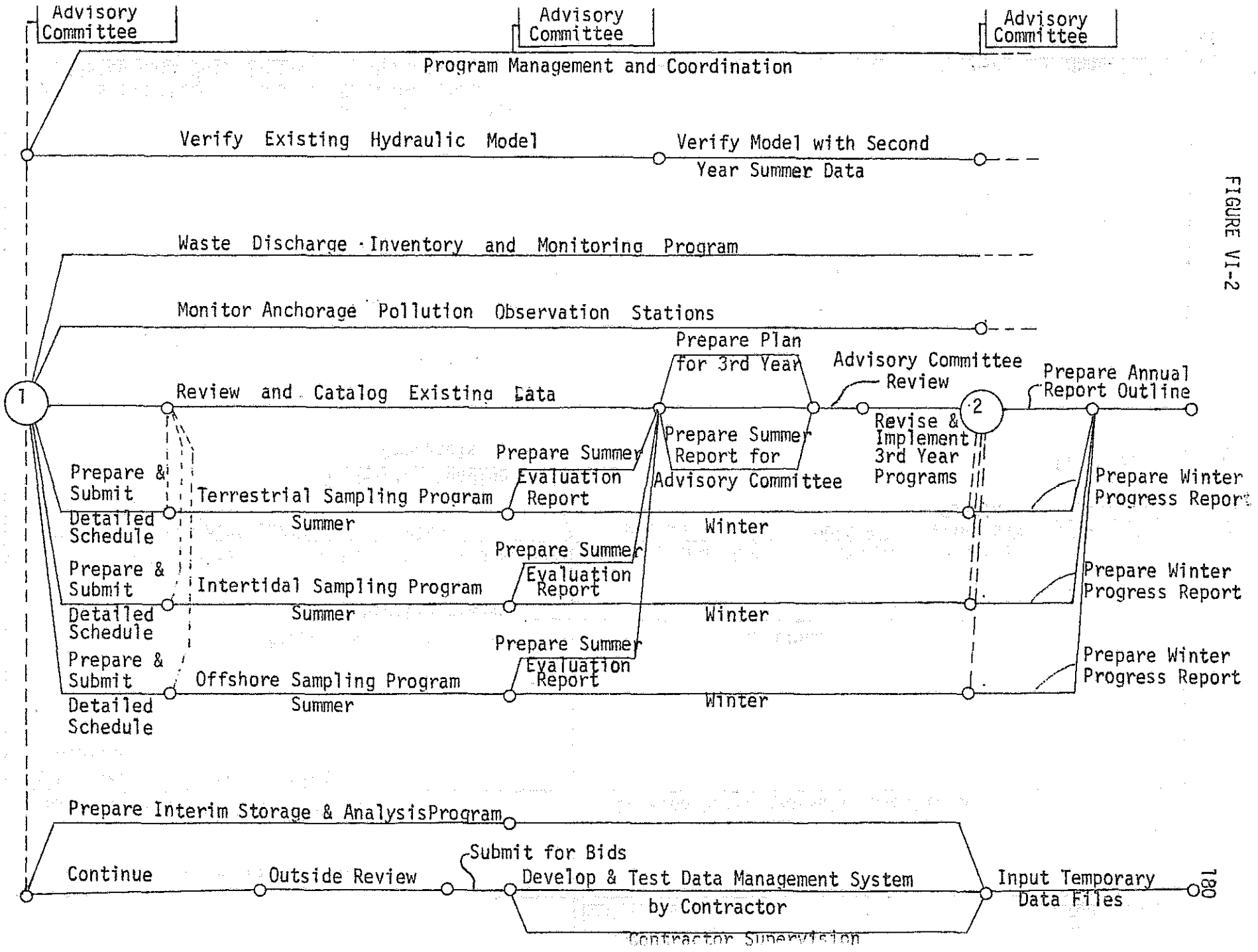
The activities during the four phases of the proposed program will begin with planning, organizing, and small scale pilot studies expanding to the full scale oceanography program, data storage facilities and an expanded mathematical simulation model of the hydrography, chemical budget and current of Cook Inlet. During the last stage of the four-phase program, data will be analyzed, field investigations will be concluded, and summary reports will be written.

First Phase. The activities of the program during the first phase will exist on four separate levels. With a program of the magnitude proposed within this report, it is necessary to properly plan and organize the activities to take place both in the field and laboratory. A program director, manager and engineering staff should be hired to act as a permanent management group during the four phases of the program to coordinate projects, write progress reports and advise contractors involved in the programs. This management group will, during the first phase, develop project specifications and plans, coordinate with an advisory group of representatives of the Federal, State and local governments and the fishing and industry groups. Funding proposals will be written and submitted and the data collection programs implemented.



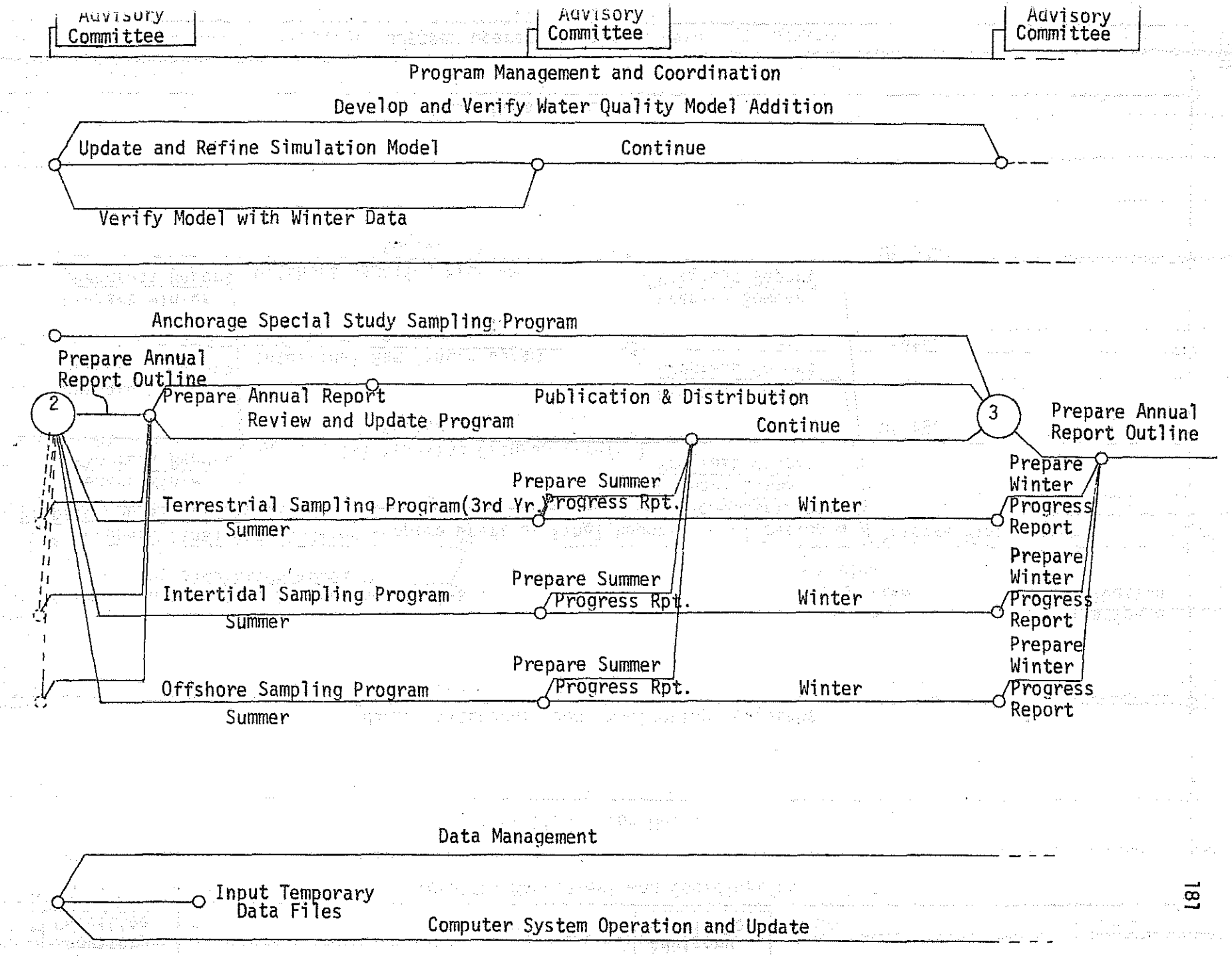
PHASE 1

FIGURE VI-1



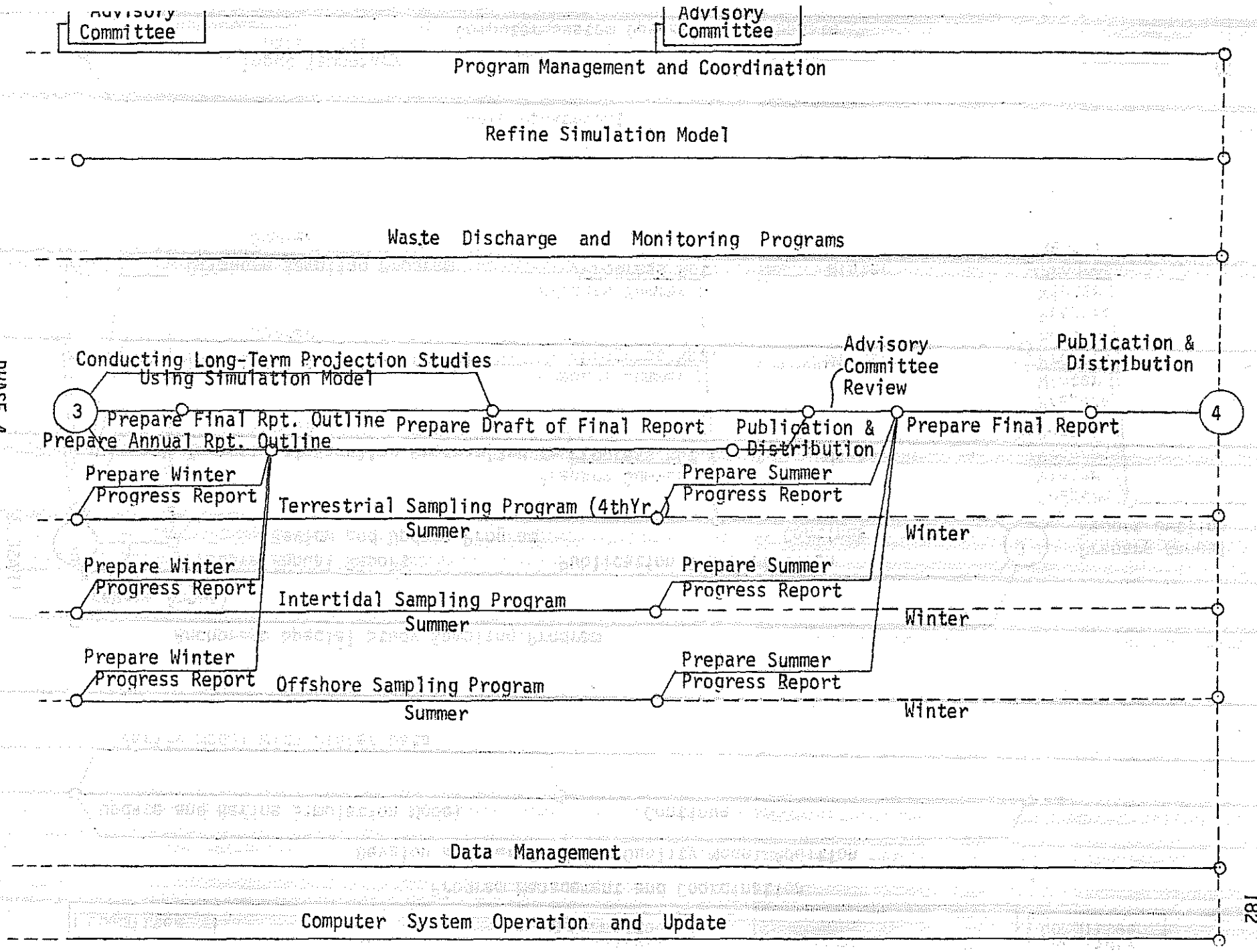
PHASE 2

FIGURE VI-2



PHASE 3

FIGURE VI-3



PHASE 4

FIGURE VI-4

Proposals will be submitted to develop a basic hydraulic model of Cook Inlet. The personnel of the Institute of Water Resources, and the Institute of Marine Science have initiated development of a mathematical simulation model and this activity will be incorporated into the Cook Inlet program.

To provide the necessary data storage and analysis capabilities, proposals will be prepared and submitted to develop a data storage facility. Two persons versed in data processing and systems design will be hired and will spend the last six months of the initial phase planning and designing the computer program. A job manual will be prepared to guide system users.

Second Phase. The pilot field investigations will begin during the second phase. The program management and coordination for these investigations will be provided by the staff previously hired and will continue throughout the length of the proposed program. The activities of the management staff during the second phase will include meeting with an advisory board which provides guidance and expertise in various fields of the investigations. The engineering staff will review and catalog existing data and prepare and submit detailed schedules for the year's sampling activities. At the end of the first summer's sampling period, evaluation reports will be prepared. These will be used to prepare the sampling schedule for the third phase. A report will be submitted to the advisory committee for review. While the results of the second phase summer sampling activities are being reviewed, winter sampling will begin. The sampling station locations and sampling frequency are listed on Table VI-1. This table is referenced to the large map included at the end of this report. Progress reports will be written on the previous winter smmpling period.

During this second phase a waste inventory and monitoring program will begin and will involve effluent monitoring for chemical characteristics and flow data. It is expected that the monitoring will continue throughout the entire program. A special study will begin to study the effect of discharge of raw sewage from Anchorage on the waters of Knik Arm, Turnagain Arm, and the water of Cook Inlet adjacent to Anchorage.

In order to facilitate storage of sampling data and the waste discharge inventory, a temporary computer storage facility will be developed to handle data while the main storage and analysis program is being devleoped. Preparation of specifications and job manual for the main storage program which began during the first stage will be reviewed by an outside computer specialist and then will be opened for bids from programming consultants as explained in Chapter V (Data Storage).

TABLE VI-1

Sta. No.	Hydrologic & Hydrographic				Geologic								Physical & Chemical				Biological			
	Climate	Streamflow Gaging	Tide Temp. & Density	Current	River Sediment Quantity	River Sed. Characteristics	Sediment Sources ICE	Sed. Sces. Shoreline Cliffs	Sed. Sces. Shoals & Mudbanks	Core Samples	Bottom Sed. Characteriza.	Sediment Transport	Physical	Chem.-Circulation&Mixing	Chem.-Biological Processes	Chem.-Waste Discharges	Flora	Fauna	Plankton	Benthos
T-1																	TA	TA		
T-2																				
T-3																	TA	TA		
T-4	WK																			
T-5																	TA	TA		
T-6	WK	C			WK	WK							BW	BW	BW					
T-7																	TA	TA		
T-8	WK	C			WK	WK							BW	BW	BW		TA	TA		
T-9																				
T-10																				
T-11																	TA	TA		
T-12																	TA	TA		
T-13																				
T-14																	TA	TA		
IN1																				
IN2																				
IN3													M		M		M		M	M
IN4			C										M		M		M		M	M
IN5																				
IN6			C										M		M					
IN7													M		M		M		M	M
IN8			C										M		M	M				
IN9													M		M		M		M	M
IN10																				
IN11													M		M	M	M		M	M
IN12																				
IN13													M		M		M			M
IN14																				
IN15									M				M				M			M
IN16																				
IN17									M				M				M			M
IN18																				
IN19													M	M	M	M	M			M
IN20													M	M	M	M	M			M
IN21													M	M	M	M	M			M

K-WEEKLY, C-CONTINUOUS, M-MONTHLY, BM-BI-MONTHLY, TA-TWICE A YEAR, O-ONCE, W-BI-WEEKLY, S-SUMMER, W-WINTER

SECOND PHASE PILOT PROGRAM

STATION LOG

TABLE VI-1 (cont.)

Sta. No.	Hydrologic & Hydrographic				Geologic								Physical & Chemical				Biological			
	Climate	Streamflow Gaging	Tide Temp. & Density	Current	River Sediment Quantity	River Sed. Characteristics	Sediment Sources ICE	Sed. Sces. Shoreline Cliffs	Sed. Sces. Shoals & Mudbanks	Core Samples	Bottom Sed. Characteriza.	Sediment Transport	Physical	Chem.-Circulation&Mixing	Chem.-Biological Processes	Chem.-Waste Discharges	Flora	Fauna	Plankton	Benthos
IN22									M				M	M	M	M	M			M
IN23							W-M	TA	M				M	M	M	M	M		M	M
IN24																				
IN25							W-M		M				M		M		M		M	M
IN26													M		M		M			M
IN27													M		M		M			M
IN28													M		M		M			M
IN29									M				M		M	M	M			M
IN30																				
IN31																				
IN32																				
IN33																				
IN34													M	M	M	M	M		M	M
IN35																	M		M	M
IN36													M	M	M	M	M		M	M
IN37													M	M	M	M	M		M	M
IN38								TA												
IN39																				
1																				
2											TA		M	M	M		M		M	M
3																				
4											S-O		M	M	M		M		M	M
5											TA	TA	M	M	M		M		M	M
6				BM						O	TA	TA	M	M	M		M		M	M
7											TA	TA	M	M	M		M		M	M
8											TA		M	M	M		M		M	M
9																				
10											TA		M	M	M		M		M	M
11																				
12											TA	TA	M	M	M		M		M	M
13				BM						O	TA	TA	M	M	M		M		M	M
14											TA	TA	M	M	M		M		M	M
15																				
16																				
17																				

SECOND PHASE PILOT PROGRAM

STATION LOG

TABLE VI-1 (cont.)

Sta. No.	Hydrologic & Hydrographic				Geologic								Physical & Chemical				Biological			
	Climate	Streamflow Gaging	Tide Temp. & Density	Current	River Sediment Quantity	River Sed. Characteristics	Sediment Sources ICE	Sed. Sces. Shoreline Cliffs	Sed. Sces. Shoals & Mudbanks	Core Samples	Bottom Sed. Characteriza.	Sediment Transport	Physical	Chem.-Circulation&Mixing	Chem.-Biological Processes	Chem.-Waste Discharges	Flora	Fauna	Plankton	Benthos
18											SO	SO	SM	SM	SM		SM		SM	SM
19										0	TA	SO	SM	SM	SM		SM		SM	SM
20											S-0	S-0	SM	SM	SM	SM	SM		SM	SM
21																				
22				SBM							S-0		SM	SM	SM	SM	SM		SM	SM
23																				
24											S-0	S-0	SM	SM	SM	SM	SM		SM	SM
25										0	S-0	S-0					SM		SM	SM
26											S-0						SM		SM	SM
27																				
28				SBM							S-0		SM	SM	SM	SM	SM		SM	SM
29																				
30											S-0	S-0	SM	SM	SM		SM		SM	SM
31										0	S-0	S-0	SM	SM	SM		SM		SM	SM
32											S-0	S-0					SM		SM	SM
33																				
34				SBM							S-0		SM	SM	SM		SM		SM	SM
35																				
36											S-0	S-0	SM	SM	SM		SM		SM	SM
37				SBM						0	S-0	S-0	SM	SM	SM		SM		SM	SM
38											S-0	S-0	SM	SM	SM					
39										0	S-0		SM	SM			SM		SM	SM
40				SBM						0	S-0		SM	SM	SM	SM	SM		SM	SM
41										0	S-0		SM	SM	SM	SM	SM		SM	SM
42				SBM						0	S-0		SM	SM	SM	SM	SM		SM	SM
43										0	S-0		SM	SM	SM	SM	SM		SM	SM
44				SBM						0	S-0		SM	SM	SM	SM	SM		SM	SM

SECOND PHASE PILOT PROGRAM

STATION LOG

The computer simualtion model developed during the first stage will be verified by existing data and by data obtained from the summer sampling period during the second stage. The model at the end of the second stage should be operational in simulating the hydraulics of Cook Inlet.

Third Phase. Program management and coordination will continue. The management staff will meet with the advisory committee for information exchange and guidance. Based on results of the previous stage's summer and winter sampling, the third stage sampling activities will be reviewed and modified. It is expected at this time that a full scale field investigation can be implemented. An operational data management system and computer storage and analysis program will be available to handle the large amounts of data resulting from the large scale field sampling programs. The data held within the temporary data storage facility will be transferred to the data bank.

The Anchorage special pollution study should continue to the end of this stage and will result in a written report. The waste inventory and effluent monitoring program will continue through this year.

A water quality simulation model will be developed during this period in conjunction with the hydraulic simulation model. Also, the hydraulic model will be updated and refined and verified with data from the previous winter sampling program.

Progress reports will be submitted to the engineering staff at the conclusion of the summer and winter sampling periods of the third stage. These progress reports and the results of the second stage pilot program will be integrated into a final report to be prepared during the fourth and final stage of the proposed program.

Fourth Phase. Based on results and experience gained from the previous two year's field investigations, the fourth stage will verify oceanographic, terrestrial, and intertidal data. The summer sampling program will be the last full scale sampling study to be carried out, with progress reports submitted to the engineering staff for inclusion into the final report. It is not anticipated at this point that a winter sampling program will be initiated. Program management and coordination will continue to the conclusion of the program at which time the field investigation coordination function will cease.

The operational hydraulic and water quality simulation model will be used to make prediction studies for the Cook Inlet estuary for future anticipated water resource management and waste discharges. It is not anticipated that the usefulness of this model will cease with the conclusion of the study but will be a management tool for investigating the effect of future waste discharges to various parts of Cook Inlet.

The data management and computer storage and analysis program functions will be continued throughout the final year to provide analysis and retrieval for data to be used in the final report. Continuation of this capability past the end of the sampling program will be discussed later in this chapter under program continuation.

The engineering staff will begin preparation of the final report outline at the commencement of the last year's activities. Also an annual report of the third stages activities will be published giving the results of the previous field sampling results. The first draft of the final report containing data compilations, results, evaluations of sampling techniques used during the previous years activities, and conclusions and recommendations of the estuarine study will be submitted to the advisory committee for review and recommendations. After the report is reviewed, the progress report for the last stage's summer sampling program will have been received and it will be incorporated into the final draft report. The final report will be prepared, published and distributed. At this point the baseline environmental study will be concluded.

Project Control

During the first stage of the proposed program, the activity chart shown and described in the preceding sections of this chapter will be converted into detailed project plans. The program will be controlled by PERT (Program Evaluation and Review Technique). Throughout the length of the project, the management staff will use PERT techniques to evaluate and modify field sampling and computer operations to obtain the most efficient field sampling sequence.

Program Continuation

At the end of the four stages, the baseline data collection will be concluded and it is anticipated the program will evolve into a surveillance system. This system will be a segment of the water resource

management program for the Cook Inlet drainage basin which is described in a separate report being prepared by David L. Peterson and Associates of Anchorage, Alaska. The function of the program coordination staff for the Cook Inlet study will cease and these personnel will be used in baseline data collection activities of a similar nature in other parts of the State.

At the time of writing this report it is not known which of the proposed data collection stations would serve satisfactorily as permanent surveillance stations. It is expected that the experience gained from conducting the data collection programs and the results obtained in characterizing the environment of the Inlet will allow selection of permanent stations.

COOK INLET BASELINE STUDY PROGRAM MANAGEMENT

Existing Organizations Dealing with Water Quality

At present, organizations having direct interests in the quality and management of the water resources of Alaska exist on the State and Federal level as well as within the important industries of the State. The State and Federal agencies meet on an informal basis within the framework of the Interagency Technical Committee. The following is a description of the individual agencies and groups which have an interest in water, some of which are included in the Interagency Technical Committee.

State Agencies

Department of Health and Welfare
- Division of Public Health

Department of Public Works
- Division of Waters and Harbors

Department of Natural Resources
- Division of Lands - Water Resources Section

Department of Fish and Game
- Division of Commercial Fisheries
- Division of Sport Fish
- Division of Game
- Division of Mines and Minerals

Governor's Water Resources Board

Federal Government

- Department of the Army
  - Army Corps of Engineers
  - Army Material Command
    - Research and Development Office, U.S. Army
    - Arctic Test Center
- Department of the Interior
  - Geological Survey
  - Fish and Wildlife Service
    - Bureau of Commercial Fisheries
    - Bureau of Sport Fish and Wildlife
  - Alaska Power Administration
    - Bureau of Land Management
    - Federal Water Pollution Control Administration
    - Bureau of Reclamation
- Department of Agriculture
  - Soil Conservation Service
  - Forest Service
  - Agricultural Experiment Station, Palmer
- Department of Commerce
  - Environmental Science Services Administration
    - Environmental Data Service
    - Weather Bureau
    - Coast and Geodetic Survey
- Department of Transportation
  - Federal Highway Administration
- Federal Field Committee for Development Planning in Alaska

University of Alaska. The Institute of Water Resources and the Institute of Marine Science are two of the major research institutes at the University of Alaska. The Institute of Water Resources was established in 1964 and its original function was to coordinate all water related activities within the University, to do basic research, and to instruct classes in water resource fields. Its scope has been expanded through research grants from industry, Federal, and State agencies to include water pollution and water related environmental research investigations.

The Institute of Marine Science at the University of Alaska has in the past undertaken oceanographic investigations over the coast of Alaska and for the past three years has conducted oceanographic cruises in Cook Inlet during summer months. Many of the Institute of Marine Science projects are directed toward oceanographic basic research.

The Geophysical Institute's stated purpose is to advance knowledge of the earth and its environment in space. The programs are broad and embrace many fields of arctic and sub-arctic research. The Institute of Social, Economic and Government Research programs deal with economic development, community development, social problems, manpower development, state and local government, resources conservation and development, and other fields. These two latter mentioned institutes have provided specialized research programs in the past and up to the present time.

Advisory Groups and Organizations.

Alaska Outdoor Recreation Council
Alaska Stock Growers Association
Alaska State Chamber of Commerce
Alaska Conservation Society
North Pacific Fisheries Association
Association of Women Voters
Isaac Walton League
Sierra Club

Oil Pollution Task Force. Composed of representatives of the oil industry and state and federal agencies, the Oil Pollution Task Force works to determine means of combating oil spills and serves as a group where ideas and information can be exchanged on an informal basis. Committees within the Task Force are established to develop contingency plans for oil pollution abatement and to determine the need for research in various aspects of oil production and its impact on the environment.

Proposed Program Management Structure

The following section presents the proposed program management structure that would provide the best means of handling the large scale investigations proposed in this report. It should be realized that there are other organizations in the United States, both public and private, that would be as capable of handling a project of this magnitude. However, in view of the fact that Cook Inlet is a most unique estuary in many instances, it is felt that an Alaskan organization familiar with problems indigenous to this state would best be able to manage a study of Cook Inlet.

The need for a well organized management structure is based on review of large estuarine studies conducted in the past years in the United States, both successfully and unsuccessfully, which indicated that proper coordination of all phases of water resources investigations is of paramount importance in estuarine studies.

Functional Operation - Data Flow. Figure No. VI-5 shows the direction of the flow of data and information during the field investigations. The data bank acts as a central storage and analysis facility during field investigations and also while reports are being written. The engineering staff acts as the main coordinating group under the direction of the project director and manager.

Management. The advisory committee and the program director and manager work closely together in operating and managing the baseline estuarine study. The program director acts as the administrative officer and is closely concerned with public contact and funding problems. The program manager coordinates and handles engineering and program investigation decisions regarding contractors and scientific personnel.

The advisory committee is made up of representatives of industry, commerce, Federal, State and local agencies having a concern in the water resources of the Inlet and private organizations. It is anticipated that representatives of the petroleum, and petrochemical industry, the timber industry, and the commercial fisheries will participate in the committee. Federal agencies will include the Fish and Wildlife Service, the Bureau of Land Management, Federal Water Pollution Control Administration and others. State agencies will include the Department of Health and Welfare, Natural Resources, and Fish and Game.

Many of the organizations listed in the preceding section "Existing Organizations Dealing with Water Quality" are expected to be represented on the advisory committee. The proposed management is shown in Figure No. VI-6.

Program Cost

For costs of the optimum program, see page 195. (Table VI-2)

ALTERNATE PROGRAM

As stated at the beginning of this chapter, political and economic restraints would possibly make funding of individual investigations, described within the framework of the previously described program, more desirable. If the overall goal of characterizing the Cook Inlet were retained, these completed investigations would contribute to a complete description of the Inlet. If this approach is taken, it is then necessary to establish priorities of investigations so that the most pressing needs for estuarine data are met first, with desirable but much less important estuarine data delegated to the future when additional funding becomes available. The following section establishes priorities of needed investigations and presents estimated budgets for accomplishing these investigations. The data needs have already been described and this section will

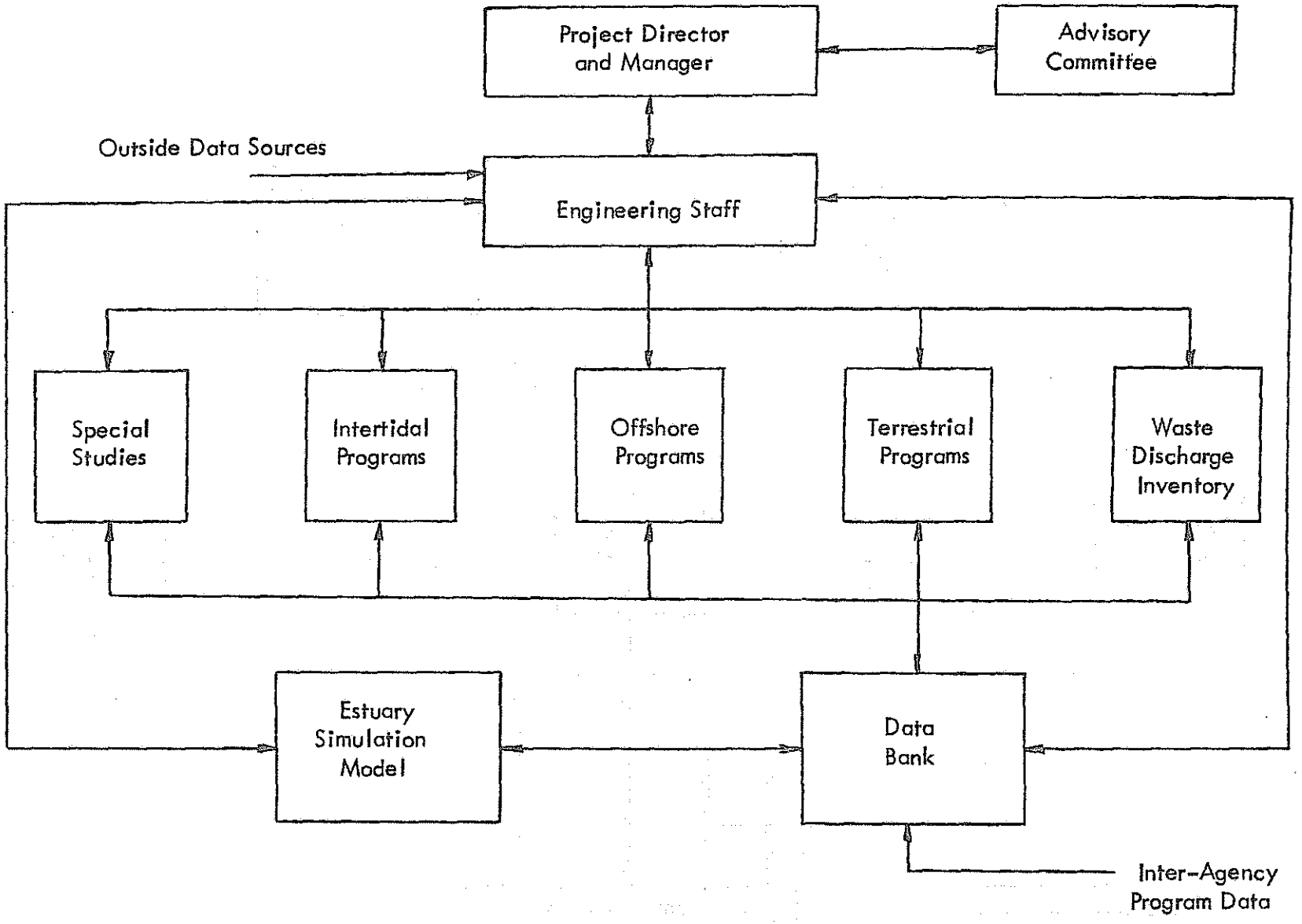


FIGURE VI-5

Data & Information Flow

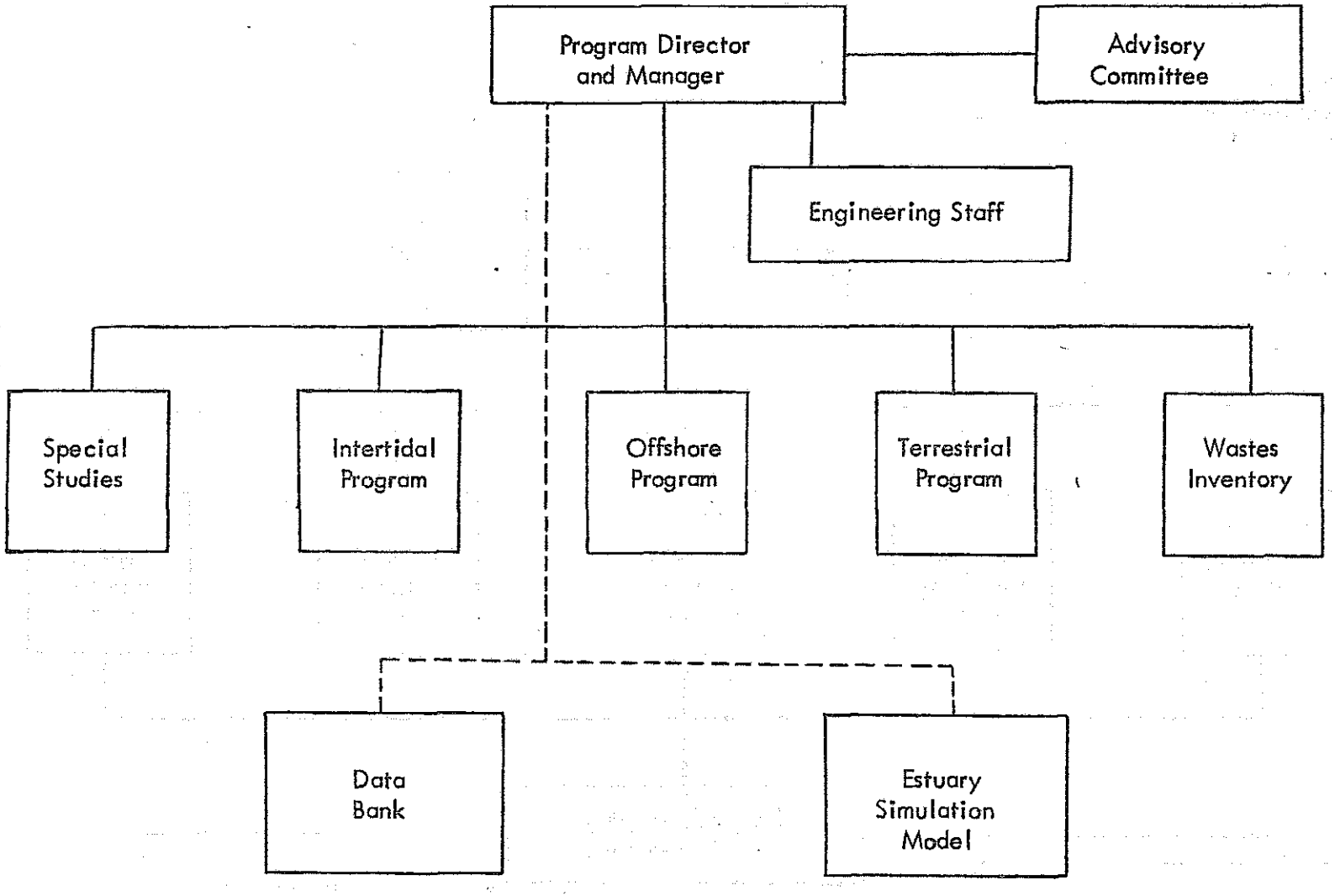


FIGURE VI-6

Management

Cost of Proposed Programs

The table below shows the estimated costs of the proposed four year program.

TABLE NO. VI-2

Activity	Phase 1	Phase 2	Phase 3	Phase 4	Total
Management	$125,000	$ 116,000	$116,000	$116,000	$ 473,000
Simulation Model	35,300	38,900	62,900	35,300	172,400
Waste Discharge Inventory		50,000	50,000	50,000	150,000
Anchorage Pollution Study		50,000	50,000		100,000
Estuarine Description (Field Investigations)		567,000	850,500	567,000	1,984,500
Data Storage and Analysis Facility	100,000	200,000	105,000	105,000	510,000
Total	$260,300	$1,021,900	$1,234,400	$873,300	$3,389,900

deal only with the areas to be investigated, the overall types of data to be collected, and the estimated costs of conducting these investigations.

As stated in the scope and objectives in the introduction to this report, the aim is to characterize the estuarine waters of Cook Inlet. The following described investigations are to be considered a step in that same direction although separate areas are to be investigated independently. For that reason and also for economy, each area should be studied intensively and in all phases as described in Table VI-1. Since visits will be made to most stations in each area to collect samples, it is more economical to collect samples for chemical analysis, sediments, and biological determinations at each visit rather than visit each station separately to collect each type of sample. It is possible that biological characterizations, and physial, chemical, and mass transport studies could be done independently but that direction of investigating to characterize each specific area is discouraged by the author.

In the following section, eleven independent investigations are described in the sequence which will yield the data of highest priority first and which also will allow the results of each investigation to contribute to planning and implementing the next investigation. It is encouraged by the author that a common method of storage of the data resulting from the individual investigations be maintained.

Investigations to be Conducted

The priority of investigations that, when completed, will characterize the complete Cook Inlet estuary is shown on Table IV-3 along with the general types of data to be collected. They are, in order of priority: Anchorage Special Pollution Study, Kenai Area Special Pollution Study, Computer Simulation Model Development, Major Waste Discharge Monitering, Area Characterization Studies - Turnagain Arm, Knik Arm, Kachemak Bay, Kamishak Bay, Upper Cook Inlet, and Lower Cook Inlet. Last in the sequence, a general wastes discharge inventory should be implemented. Table VI-4 shows the individual studies and the sampling station locations which should be used for each study. The estimated cost of each program will be presented in the following sections where each study is briefly described.

Anchorage Special Pollution Study. It is important to investigate the waters of Cook Inlet surrounding major areas of population and industry. Anchorage has the largest concentration of population in Cook Inlet and at the present time is discharging raw sewage into the Inlet. A study should be conducted to investigate the effect of the sewage discharge on the Inlet waters. Problems have occurred in the past with floating

TABLE VI-3

INVESTIGATION PRIORITIES & TYPES OF DATA TO BE COLLECTED

	Mass Transport	Sediments & Sediment Characterization	Standard Chemical & Physical Oceanography	Biologic (Basic Productivity)	Biomass & Diversity Indexes	Ecological Studies	Pollution Indicators	Pollution Oriented Chemical & Physical Sampling	Waste Discharges Complete Characteri-zation	Waste Discharges Gross Characteristics
Anchorage Special Pollution Study	X		X		X	X	X	X	X	
Kenai Special Pollution Study	X		X		X	X	X	X	X	
Computer Simulation Model										
Major Waste Discharge Monitoring									X	
Turnagain Arm	X	X	X	X	X	X	X			
Knik Arm	X	X	X	X	X	X	X			
Kachemak Bay	X	X	X	X	X	X	X			
Kamishak Bay	X	X	X	X	X	X	X			
Upper Cook Inlet	X	X	X	X	X	X	X			
Lower Cook Inlet	X	X	X	X	X	X	X			
Complete Waste Discharge Characteri-zation										X

TABLE VI-4

STATION SELECTIONS FOR SEPARATED INVESTIGATIONS
(see large map at the end of report)

Anchorage Special Pollution Study	Kenai Area Special Pollution Study	Turnagain Arm Characterization	Knik Arm Characterization	Kachemak Bay Characterization	Kamishak Bay Characterization	Upper Cook Inlet Characterization	Lower Cook Inlet Characterization
	T-13 IN-33 IN-34 IN-35 IN-36 19 20 22 23 26 29	T-11 IN-23 IN-24 IN-25 IN-26 IN-27 IN-28 IN-29 IN-30 IN-31 41 42 Plus additional oceanographic stations in upper part of arm	T-10 IN-19 IN-20 IN-21 IN-22 Plus additional oceanographic stations in upper part of arm	T-14 IN-39 7 8 Plus additional intertidal stations	T-1 T-2 IN-1 IN-2 IN-3 IN-5 4 5	T-5 T-6 T-7 T-12 IN-12 IN-14 IN-16 IN-18 IN-30 IN-32 IN-34 21 22 23 27 28 29 33 34 35 39 40 43	T-3 T-4 T-13 IN-2 IN-5 IN-7 IN-8 IN-10 IN-11 IN-35 IN-38 IN-39 1 2 3 6 9 10 11 13 15 16 17 19

solids being deposited ontide flats and beaches. The investigation should consider the effect of suspended and dissolved substances on the water. Currents, tides, the effect of high silt concentrations on sewage discharges, and the effect of primary treatment of the sewage on the ecological environment of the surrounding area, should be investigated. The estimated cost of this investigation is $150,000. Approximately two-thirds of this study has already been funded and work will begin during the latter part of 1969. The Institute of Water Resources will begin investigation of tides, currents and the effect on the biology of the Inlet adjacent to Anchorage.

Kenai Area Pollution Study. The next area of interest is the Inlet waters adjacent to the Kenai-Nikiski industrial area. Several petrochemical industries are being constructed and one industry is in operation at the present time. The chemical and biological conditions should be investigated under the influence of the petrochemical waste discharges to the Inlet. The types of data needed to evaluate the effects of pollutants was described in Cahpter IV. The sampling stations to be used are listed in Table VI-4 and are referenced to the large map at the end of this report.

The Institute of Marine Science has completed limited oceanographic work in this area and have also done some chemical monitoring on one waste outfall. It is expected that a complete determination of the conditions of the Inlet waters will be needed within a very short time as a greater number of industries go on-line. The estimated cost of this investigation will be approximately $150,000 and will require one year to complete. The types of samples and sampling frequencies are listed in Table VI-1.

Major Wastes Discharge Monitering. In order to begin to characterize the Cook Inlet estuary, the major waste inputs must be monitored to determine the source and amount of waste constitutents that will be found in the estuarine waters. The types of analysis and monitering method was described in Chapter IV (Waste Discharge Inventories). The major domestic and industrial discharges should be characterized and monitored continuously. This activity is expected to cost approximately $30,000 per year.

Computer Simulation Model. Also important, is a computer model simulating the hydraulics and quality conditions of the estuary. This should be completed and tested with existing data before any major area characterization investigations are begun. A limited approach to development of this model has been initiated by the Institute of Marine Science and the Institute of Water Resources, both at the University of Alaska. It is expected to cost approximately $50,000 to complete this model.

Areal Investigations within Cook Inlet. After the major waste discharges are monitored and a simulation model is developed, characterization investigations can be initiated within Cook Inlet. The major area exclusive of Knik and Turnagain Arms, and Kachemak Bay and Kamishak Bay is a large and difficult body of water to study and it is proposed that the above mentioned arms and bays be characterized first in order of their importance to determine their inputs and influence on Cook Inlet. The sequence of study should be 1) Turnagain Arm, 2) Knik Arm, 3) Kachemak Bay, 4) Kamishak Bay, and then 5) Upper Cook Inlet and 6) Lower Cook Inlet. The data needs are the same for all the investigations and were described in Chapter IV. In general, mass transport, sediments, standard physical and chemical oceanographic, basic biological productivity, biological biomass and diversity indexes, and the ecology should be investigated for each area. Table IV-3 and Table VI-4 list the types of data and sampling stations to be used in these areal characterizations. The approximate costs for each investigation are: Turnagain Arm - $150,000, Knik Arm - $150,000, Kachemak Bay - $100,000, Kamishak Bay - $100,000, Upper Cook Inlet - $500,000, and Lower Cook Inlet - $500,000.

Complete Wastes Discharge Monitoring. As smaller communities grow larger under the impact of the fishing, petroleum, and general population influx to Alaska, the communities along the shores of Cook Inlet will begin diverting domestic sewage from home septic tanks to community sewage treatment systems. It will be important to monitor the discharges from these various collector and treatment facilities, so that the impact of the wastes discharges to Cook Inlet can be monitored. The data needs in establishing an inventory and monitoring system have been discussed in Chapter IV. It is expected that this activity can be implemented for $30,000 a year.

SUMMARY

This chapter has presented the means by which the proposed program can be implemented and funded. Two programs were proposed, 1) a comprehensive program of four phases in which planning, data storage and management, sampling, and data evaluation were combined to insure rigorous control of the program and achievement of the desired goals of characterizing Cook Inlet physically, chemically, and biologically. The program cost was approximately 3.4 million dollars. it is recognized that this is a high price tag for a study but past studies have indicated that a program yielded less than desirable results if the proposed program were not rigorously managed all the way through to completion.

An alternate program was proposed with individual studies arranged in a sequence of priorities so that information of need "today" was obtained "today" and information of lesser importance but desirable, was put in the future.

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Appendix A

OIL FIELDS AND STATISTICS
COOK INLET

Excerpted from 1967 Annual Report
State of Alaska
Division of Mines and Minerals [48]

Middle Ground Shoal Field
Cook Inlet, Alaska
Shell Oil Company and Pan
American Petroleum Corporation, Operators

Location	T10N & 11N, R11W &12W, Seward Meridian
Discovery Well	Pan American Pet. Corp. - Middle Ground Shoal State No. 1
Discovery Date	June 10, 1962
Producing Formation	
Oil	Kenai - 5,185' - 8,100' Hemlock - 7,329' - 9,500'
Deepest Test	Pan American Pet. Corp. MGS 17595 No. 2 10,862' (VD)
Wells	
Oil - Flowing	20
Gas Lift	10
Water Injection	1
Shut-in	1
Total	32

Production Data - 1967

	Field Total	"A" Pool	"B,C,&D"Pools	"E,F,&G"P
Oil Production - bbls.	7,408,091	127,817	1,913,271	5,367,0
Water Production - bbls.	156,290	49,049	63,151	44,0
Casinghead Gas - MCF	3,214,803	186,422	1,035,113	1,993,2

Granite Point Field
Cook Inlet, Alaska
Mobil Oil Corporation and Pan
American Petroleum Corporation, Operators

Location	T10 & 11N, R11 &12W, Seward Meridian
Discovery Well	Mobil Oil Corporation, Granite Point #1
Discovery Date	June 9, 1965
Producing Formation	Kenai Zone - 7,750' - 10,200'
Deepest Test	Pan American Pet. Corp., Tyonek State 17587 No. 2 - 12,288'
Wells	
Oil - Flowing	16
Gas Lift	0
Shut-in	0
Production Data - 1967	
Oil Production	7,053,064 bbls.
Water Production	50,483 bbls.
Gas Production - with oil	4,889,550 MCF (base 14.65 psi)

Swanson River Field
Kenai Peninsula, Alaska
Standard Oil Company of California,
Western Operations, Inc., Operator

Location	T7N & 8N R9W, Seward Meridian
Discovery Well	SRU 34-10
Discovery Date	August 24, 1957
Producing Formation	
Oil	Hemlock Zone - 10,150' - 11,700'
Gas	Kenai - 3000' - 5800'
Deepest Test	SCU 22A-32 - 14,796'
Wells	
Oil - Flowing	32
Gas Lift	4
Shut- in	12
Gas - Producing	0
Shut-in	6
Salt Water Disposal	2 (One is dual - gas producer [shut-in] and disposal)
Gas Injection - Active	9
Idle	0
Production Data - 1967	
Oil Production	12,980,482 bbls.
Water Production	12,257,904 bbls.
Gas Production - with oil	13,541,028 (base 14.65 psi) MCF
Gas Production - gas wells	0

Trading Bay Field
Kenai Peninsula, Alaska
Union Oil Company of California, Operator

Location	Sec. 3 & 4, T9N, R13W	
Discovery Well	Union Oil Company, Trading Bay 1-A	
Discovery Date	June 1, 1965	
Producing Formation		
Oil	Upper Kenai Upper Hemlock	
Gas	Upper Kenai	
Deepest Test	Atlantic Richfield Trading Bay State #1 - 10,950'	
Wells		
Oil - Flowing	5	
Gas Lift	3	
Shut-in	2	
Gas - Producing	1	
Total	11	
Production Data - 1967	Middle Kenai Zone	Hemlock Zone
Oil Production	135,634 bbls.	591,360 bbls.
Water Production	158 bbls.	620 bbls.
Gas Production - with oil	204,927 MCF(base 14.65 psi)	469,725 MCF(base 14.65 psi)
Gas Production - gas wells	47,268 MCF	0

McArthur River Field
Trading Bay Unit
Union Oil Company of California, Operator

Location	T8N 9N - R13W, Seward Meridian
Discovery Well	Union Oil Company Grayling No. 1-A
Discovery Date	October 24, 1965
Producing Formation	Hemlock Zone
Deepest Test	Shell Forelands Channel State No. 1-A 11,786' Drilled, 11,736' TVD
Wells	
Oil - Flowing	3
Gas Lift	0
Shut-in	0
Total	3
Production Data	
Oil Production	748,815 bbls.
Water Production	771 bbls.
Gas Production - with oil	219,915 MCF (base 14.65 psi)

Kenai Gas Field
Kenai Peninsula, Alaska
Union Oil Company of California, Operator

Location	T4 & 5N - R11 &12W, Seward Meridian
Discovery Well	Kenai Unit No. 14-6
Discovery Date	October 11, 1959
Producing Formation	Kenai 4,240' - 5,728'
Deepest Test	No. 14-6 - 15,047'
Wells	
Producing	17
Shut-in	1

Production Statistics

	Number of Wells			Gas Produced - MCF	
Year	Producing	Shut-in	Water (bbls)	Year	Cumulative
1960	2	0	0	14,474	17,474
1961	3	2	0	214,718	232,192
1962	3	2	0	1,460,175	1,692,367
1963	3	2	0	3,105,539	4,797,906
1964	4	2	0	4,493,170	9,291,076
1965	6	6	0	5,985,342	15,276,418
1966	10	2	0	33,374,960	48,651,378
1967	17	1	0	39,615,964	88,267,342

Kenai Deep Gas Field
Kenai Peninsula, Alaska
Union Oil Company of California, Operator

Location	Sec. 6, T4N - R11W, Seward Meridian
Discovery Well	Kenai Deep Unit No. 1
Discovery Date	November 13, 1967
Producing Formation	Kenai 9,155' - 9,230'; 9,535'-9,720'
Deepest Test	Kenai Unit No. 14-6 drilled to 15,047'
Wells	
Producing	0
Shut-in	1

Production Statistics

Year	Producing	Shut-in	Water(bbls)	Year	Cumulative
1967	0	1	0	8,000	8,000 Test Prod.

Sterling Gas Field
Kenai Peninsula, Alaska
Union Oil Company of California, Operator

Location	Sec. 15, T5N-R10W, Seward Meridian
Discovery Well	No. 23-15
Discovery Date	August 4, 1961
Producing Formation	Kenai 5,250' - 54' (perforations)
Deepest Test	No. 23-15 - 14,832'
Wells	
Producing	1
Shut-in	1

Production Statistics

Number of Wells

Year	Producing	Shut-in	Water	Year	Cumulative
1962	1	0	0	25,186	25,186
1963	1	1	0	45,724	70,910
1964	1	1	0	58,383	129,293
1965	1	1	0	120,319	249,612
1966	1	1	0	157,490	407,102
1967	1	1	0	179,544	586,646

Appendix B

FISHERIES AND SHELLFISH PROCESSORS IN COOK INLET [2]

PROCESSORS FILING AN INTENT TO OPERATE FOR COOK INLET - 1968

Company Name	Plant Location
Lester Acord	Anchorage
Alaska Star, Inc.	Beluga River
Alaskan Seafoods, Inc.	Homer Spit
Alaskan Smokey Joes	Anchorage
F. Alioto Fish Co.	Homer
Arctic Fisheries	Homer Spit
Berman Packing Co.	Ninilchik
Millard L. Brewster	Homer
C & M Seafoods	Anchorage & Homer
Cohen Trading Co.	Clam Gulch
Columbia - Wards Fisheries	Kenai
Crab Pot, Inc.	Anchorage
Dan's Cold Storage	Ninilchik
Bud S. Deitz	Homer
Ekren Packing Co.	Kasitsna Bay
Far East Trading Co.	Ninilchik
Fayjan's Fish Market	Anchorage
Gardner Seafoods	Homer
Charles L. Hunley	Anchorage
Torvald Jensen	Ninilchik
Vern Johnson	Anchorage
W. P. Johnson, Jr.	Anchorage
Keener Packing Co.	Kalifonsky Beach
Kenai Packers	Kenai
Luba Moser	Clam Gulch
Virgil Myers	Anchorage
North Kenai Cold Storage	Kenai
Osmar's Ocean Specialties	Clam Gulch
Calvin Parks	Anchorage
Delbert G. Phillips	Halibut Cove
Puget Sound Salmon Egg Co.	Snug Harbor

PROCESSORS FILING AN INTENT TO OPERATE FOR COOK INLET - 1968
(Continued)

Company Name	Plant Location
R & F Seafood Processors	Anchorage
R-Lee Company	Kalifonsky Beach
B.P.M. Fishery Products	Anchorage
G. S. Richmond	Anchorage - M/V Iceland
Charles L. Simon Seafoods	Kasilof
Smoked Alaskan Seafoods	Clam Gulch
Snug Harbor Packing Co.	Snug Harbor
Sportsman's Cannery	Clam Gulch
Sterling Sausage Co.	Sterling
Tidewater Packing Co.	Anchorage
Wakefield Fisheries	Seldovia
The Waterfall Fisheries Corp.	Kasilof
Whitney - Fidalgo Seafoods, Inc.	Port Graham & Anchorage

1967 COOK INLET PROCESSORS

PRODUCTION WASTE

Company Name	Location	Primary Product
Alaska Star Inc.	Beluga River	Smoked Salmon
Alaskan Seafoods, Inc.	Homer	King Crab (Fresh-Frozen)
Alaskan Smokey Joes	Anchorage	Smoked Salmon
Berman Packing Co.	Ninilchik	Canned Salmon (Fresh-Frozen)
Columbia-Wards Fisheries	Kenai	Canned Salmon, Salmon Eggs
Dan's Cold Storage	Ninilchik	Frozen Salmon, Halibut Frozen
Ekren Packing Co.	Kasitsna Bay	Smoked Salmon, Halibut Frozen (King Crab, Dungeness Crab & Clams Canned)
Torvald Jensen & Co.	Ninilchik	Smoked Salmon
Keener Packing Co.	Kalifonski Beach	Salmon Frozen, Fresh, Kippered
Kenai Packers	Kenai	Canned Salmon
Osmar's Ocean Specialties	Clam Gulch	Canned Salmon & Fresh
R-Lee Company	Soldotna	Frozen & Fresh Salmon
Seapack	M/V Teddy	Fresh-Frozen Salmon
Simon Seafoods	Kasilof	Smoked Salmon
Smoked Alaskan Seafoods	Clam Gulch	Smoked Salmon
Snug Harbor Packing Co.	Snug Harbor	Canned Salmon
Tee Pee Cold Storage	Kenai	Fresh-Frozen Salmon
Tidewater Packing Co.	Anchorage	Smoked Salmon
Wakefield Fisheries	Seldovia	Halibut Fresh-Frozen, King Crab Fresh-Frozen
Whitney Fidalgo Seafoods	Anchorage	Canned Salmon
Total Estimated Waste		5,630,500 lbs.

Appendix C

Excerpts from
PROBLEMS OF SETTING STANDARDS AND OF
SURVEILLANCE FOR WATER QUALITY CONTROL

by

State Water Quality Control Board
The Resources Agency
State of California
1967

a. Spatial Variation

There is little doubt that estuarial systems represent the most complex form of quality environment. Not only are these systems complex from the hydrologic and hydrodynamic points of view, but the mixing of fresh and saline waters, each with its separate constituents, adds another dimension to the problem of quality characterization. Add to this the tendency for concentration of waste producing sources in estuarial regions and the wide variety of industrial pollutants which may be expected in such waters and one begins to appreciate the enormity of the problem.

The spatial variation of water quality in estuaries depends on their configuration which is, in turn, controlled to an important degree by the characteristics of coastal mountain masses. Estuaries along the California coastline range between the extremes of the relatively short, steep and relatively simple terminal reaches of the north coastal streams (Smith and Klamath Rivers) and the extensive and exceedingly complex estuary of the Sacramento-San Joaquin River System. The north coastal estuaries are fed by wild streams with relatively little regulation which drain mountainous areas of high rainfall. Consequently, they experience large fluctuations in seaward flow and tend to be deep and narrow. Flows are generally unidirectional in these estuaries and less inclined toward lateral circulation, branching, and stratification.

Some of the smaller coastal drainages are so small that dry weather flows are not adequate to overcome the effects of ocean processes and their estuaries may tend to become periodically choked or even sealed off by accumulated sand and sediment. Such estuaries become virtually a series of small lakes or lagoons during dry periods. This is especially likely to be the case along the southern coastline where littoral drift is large and tidal amplitude is small.

Estuaries may be classified in degree of spatial complexity as 1-, 2-, or 3- dimensional. A "one-dimensional" estuary is one in which the flow is unidirectional with the principal axis of the stream and in which turbulence

is sufficiently great as to preclude the development of stratified flow. Two types of two-dimensional estuaries are identified: a) one in which lateral as well as longitudinal motion is possible but the system remains fully mixed in the vertical, and b) one in which flow in constrained to the longitudinal axis but may be stratified by salinity differences along the vertical axis. A three-dimensional estuary is defined as one in which flows are longitudinal and lateral and as well has a pronounced gradient in the vertical.

The degree of lateral motion which may occur in an estuary depends both on its configuration and on the stability of discharge through the estuary. A customary pattern is for the estuary to widen rapidly as the stream becomes identified with the ocean environment. This has the effect of both facilitating lateral motion by removing the physical constraint and reducing the net flow velocity by widening of the transverse section. In the latter instance the discharge, particularly at low levels, would be inclined to become unstable, with circulation controlled more by tidal action than river flow.

Stratification occurs in estuarial waters in situations where estuaries are relatively deep and protected from wind action and where fresh water outflows are sustained at adequate levels. Generally speaking, the deep, steep estuaries of the north Pacific coast are well stratified. The broad, shallow estuaries of the southern coast including terminal embayments tend to be well-mixed and little stratified except near their contact with the ocean. Certain estuaries which accommodate wild streams with large Q_{max}/Q_{min} ratios may at certain times be stratified and at others be completely mixed.

Stratification may be especially important in the effect it has on transport of pollutants. It may constrain pollutants to move with one stratum or another and may limit the quantity of dilution water available for disposal of a concentrated waste discharge. Also, it may tend to increase the rate of excursion of certain quality constituents identified with estuarial inflow so that their detention in the estuarial region is less than might be expected in unstratified (vertically mixed) estuaries.

b. Temporal Variation

The characteristic time-dependent variations in quality of estuarial waters derive principally from two phenomena: oceanic tidal motion, and the hydrology of the tributary drainage basin. One of these is fundamentally a periodic phenomenon and the other is largely random in character. Consequently, a quality characterization program should be designed with due regard to the time period of major importance to quality control and with appropriate proportionate emphasis on tidal and hydrologic behavior.

Tidal motions in an estuarial environment are produced by a complex superpositioning of a large number of periodic phenomena plus some randomness introduced by meteorologic, climatic, and hydrologic events. The latter are largely unpredictable and usually neglected, except in a few rare instances where prevailing wind effects account for significant changes in tidal amplitude and circulation. Periodic components derive chiefly from movement of celestial bodies and, hence, they corrrespond closely in period to the diurnal, lunar, and solar cycles. The order of importance in effects on water quality are as listed above, with the diurnal effect dominating, the lunar cycle accounting for some minor differences, hardly discernible beneath random hydrologic influences, and the solar cycle being of little importance. For most practical purposes the tidal effect can be treated as fundamentally diurnal with extreme ranges determined by the lunar period ($\sim$ 29 days).

Tides of the Pacific Coast are of a mixed type, consisting of two fluctuations, from low to high to low each lunar day ($\sim$ 25 hours). The extreme positions of the tide are designated as "high-high" or "low-low" and the secondary maxima and minima as "low-high" and "high-low". Tide tables usually provide information on the mean values of the extremes (MHHW and MLLW) and of all highs and lows (MHW and MLW) together with the predicted times and positions of extremes. Mean tidal range (MHW minus MLW) along the California coastline varies from about 4.1 feet at San Diego to approximately 5.1 feet at Crescent City. The average differences of the daily extremes, MHHW minus MLLW, are about 5.7 feet and 6.9 feet, respectively.

The characteristic pattern of tidal fluctuation in the ocean per se is significantly modified as the tide wave enters and progresses up the estuary. The physical configuration of the estuary, its elevation-volume relationship, its frictional properties and the rate of stream runoff all tend to determine the rate of movement of the tide wave and its amplitude at various points within the system. The amplitude of the wave may either be increased or decreased depending on the relative importance of these factors and the consequences of such hydrodynamic wave phenomena as reflection, refraction, and resonance. It is abundantly clear that the pattern of tidally induced motions is extremely complicated and predictable only through application of extremely painstaking and exacting mathematical procedures.

Of greatest direct significance in estuarial quality studies are those properties which determine the disposition of quality constituents carried into the system by hydrologic inputs or by direct waste discharge. The most important of these properties for a point within the system are the periodic histories of velocity, discharge, and turbulence. Velocity and discharge are determinable from the tidal hydrodynamic and hydrologic characteristics of the estuary and exhibit fluctuations which are similar in pattern to but differing in phase from tidal elevation fluctuations. Both contain hydrologic components which are of greater or lesser importance than the tidal influence depending on the stage of stream runoff. These components determine the net movement of quality constituents seaward (or landward in certain special cases).

Turbulence in estuaries, often a controlling factor in the disposition of pollutants, is difficult to define either physically or mathematically. It is usually interpreted in the form of a mixing coefficient which depends both on the hydrodynamic state of the system (velocity, frictional resistance, etc.) and the scale of the system (depth, volume, and/or width). The degree of turbulence or mixing is also a function of time and space, varying widely from place to place and according to the stage of tidal motion. It must be determined either empirically or by direct observation on the prototype.

The mixing properties of the estuary are especially important in that they determine the potential for landward advance of quality constituents

which are identified with the lower extremities of the estuary. The tendency for intrusion of such constituents against the seaward flow of fresh water is determined by the preponderance of mixing effects over those of hydrologic throughput and lead to another definition of estuaries as follows:

Positive estuary--an estuary in which the net movement of fresh water entering the upper end is seaward.

Negative estuary--an estuary in which the net movement of seawater entering the lower end is landward.

Neutral estuary--an estuary in which there is no net movement of seawater or fresh water either landward or seaward.

It will be recognized that an estuary may, over an annual hydrologic cycle, be defined according to all three criteria and that the definition may not apply equally well to all portions of the estuary at the same point in time. Nevertheless, this classification provides some appreciation of the relative importance of estuarial transport processes. As examples of the several types one may observe that southern San Francisco Bay is a negative estuary, the central portion at low runoff periods is nearly neutral, and the northern bay is usually positive. At points further upstream in the Sacramento-San Joaquin Delta the system may become negative at times of high consumptive demand.

In summary, it may be concluded that the temporal variations in quality of estuaries are most closely related to the tidal cycle over short periods and to the hydrologic cycle over periods of a year or longer. From the standpoint of surveillance and quality characterization, the dominant time period is determined by the balance between tidal hydrodynamic effects and the influence of the hydrology of the tributary drainage.

c. Quality Constituents

Dissolved minerals: The distribution of dissolved mineral constituents in estuarial environments is often of considerable concern to water users in adjacent areas, especially if the tributary drainage flow is regulated. Of special significance are the intrusion of saline waters from the sea and the migration of agricultural drainage flows carried into the upper reaches of the estuary.

In estuaries which are fully mixed in the vertical, due to the dominance of tidal over hydrologic effects, a salinity gradient tends to become established at a configuration which reflects the spatial variation in estuarial properties. If hydrologic conditions are well controlled the gradient will tend toward a "dynamic" equilibrium in which the maximum and minimum values of salt concentration are directly correlatable with the stage and phase of the tide. The movement of the water mass up and down the estuary involves two counteracting effects: the advective transport of salt seaward with the stready hydrologic flow and the "diffusional transport" landward as a consequence of mixing. The degree of penetration of the salt is controlled in such a case, for a given set of tidal conditions and a given geometric configuration, solely by the hydrologic boundary conditions.

Salinity gradients in stratified estuaries are far more complicated. In the absence of a force to induce complete mixing in the vertical, there exists a tendency for the water masses to move more or less independently. Consequently, sea water may move landward near the bottom of the estuary at the same time fresh (or brackish) waters are moving seaward at the surface. In relatively deep, protected estuaries this phenomenon becomes accentuated at times of high runoff. Of course, such estuaries are most likely to be found along coastlines where tidal amplitudes are greatest and natural river flows are high.

In a stratified estuary the degree of stratification is usually greatest at some point near the mouth of the estuary and diminishes as one moves landward up the estuary. Tidal oscillation within the estuarial system tends to displace the pattern of salinity distribution, in this case also, so that under a given set of tidal conditions and constant outflow a "dynamic"equilibrium can be achieved. The observer would note a repetitive pattern of salinity both in time and space if he were to carry out a succession of observations. Although equilibrium is rarely achieved in natural systems, it would probably be more rapidly established in stratified than well-mixed estuaries, if only for the reason that mixing processes are less dominant.

It should be recognized that the distribution of the dissolved mineral constituents identified with fresh water inflows to an estuarial system is not necessarily proportional to the "concentration" of fresh water in the system. Not only are inflows highly variant in quality but the estuary constitutes a highly active zone in which physio-chemical reactions and biologic effects may appreciably modify concentrations of minerals, particularly those not dominant in sea water.

Dissolved organics: Organic matter enters the estuary from a multiplicity of sources, both of fresh and salt water origin and arising from the concentration of industrial, municipal, and agricultural wastes. Accordingly, there are significant demands for these materials created by the innumerable forms of life which persist in the estuarial environment. These demands are distributed with all the complexity inherent in estuarial systems with the result that the fate of a given constituent may be virturally impossible to predict.

It might be supposed that organic materials would be transported through an estuary by the normal hydro-mechanical processes which determine the fate of inflowing water and that these materials would be acted upon by agents of degradation along the way. Regretably (from the point of view of surveillance) biological degradation processes are closely related to environmental conditions and the agents which can survive thereunder. The estuary provides the least favorable environment for many degradation processes, the kinetics of which vary widely in such systems in both space and time. Only a completely dynamic approach has any real hope of accommodating, in a rational way, the multifarious interactions which determine the fate of organic constituents in estuaries. It must suffice to observe at this juncture that the problem is not sufficiently understood to allow formulation of more than the most rudimentary surveillance criteria.

Suspended particulates: The natural erosion of uplands insures a continuing supply of suspended particulates to the estuarial regions. This material may be flocculated under the influence of brackish waters in the estuary and deposited and redistributed by the complex hydrodynamic motions of estuarial waters. The action of the tides, the natural surface inflow,

excavation or filling activities, wind and wave action, and the salinity of the water all have important roles in determining the quality of material which remains in suspension for ultimate transport seaward and the quantity which will become resident in the estuary.

There is a natural tendency, given a steady supply of suspended material, to establish an equilibrium between the supply of new sediments, the displacement of old sediments, the quantity retained in deposits, and the quantity maintained in suspension. If flows and concentrations are steady, the rates of change in quantity of suspended and deposited material are constantly zero. However, if the processes of scour, resuspension, flocculation, etc., are continually changing then these rates are also continually changing from place to place and time to time.

In the estuary a dynamic equilibrium can be achieved only so long as the fluctuations in sediment supply and in those forces or factors which tend to move sediments are periodic. In practice, equilibrium is hardly ever achieved for the reasons that: 1) random effects of wind and wave action play a dominant role in sediment resuspension in shallow embayments, 2) annual periods of sediment production contain large random components, and 3) man is continually modifying the configuration of the estuarial environment. It can be anticipated that for most estuaries terminating in large embayments the monitoring of suspended sediment concentration would reveal a pattern which could be characterized almost wholly as statistical. That is to say, random influences in such estuaries mask the effects of short term periodic phenomena on this quality parameter.

Another effect of considerable significance in the estuarial quality picture is that of limitations in light penetration into embayments by virtue of suspended sediment load. In very shallow estuaries with vigorous wave action or those which are well-mixed for other reasons, the availability of light to support photosynthetic activity in the aquatic environment is controlled largely by random factors. On the other hand, in estuaries where wind and wave action is not sufficient to destroy the stability of stratification, sediments may be confined to limited zones depending on: 1) the source with which they were originally indentified before entering the estuary, and 2) the character of the sediment load, itself. In many such

estuaries turbid waters move through the upper zones, avoiding the influence of brackish waters until they are carried into the ocean where flocculation and deposition occur. In others, where the sediment load actually increases the fluid density slightly, the sediment-bearing water may enter the system at a subsurface location or even flow through the estuary near its bottom.

Dissolved gases: Because estuaries are often the depositories of organic wastes, both dissolved and settleable, and because of their hydrodynamic complexity the concentration of dissolved oxygen and other dissolved gases related to the decomposition processes are not easily predicted or evaluated. This becomes all the more obvious when one considers the classic "oxygen sag" problem for an estuary.

The oxygen resources of the system derive from four major sources: 1) inflowing fresh water streams, 2)surface reaeration, 3) intrusion of saturated sea water, and 4) photosynthesis. The first two of these are elements of the classic "sag" problem for a stream, which for the present case must be examined in light of the unique dynamic behavior of the estuarial environment. The third and often neglected source can be of considerable consequence in stratified estuaries, particularly where the possibility of coastal "upwelling" exists. The fourth source, photosynthesis, has just recently begun to receive attention. It is, of course, related to the diurnal cycle and to the ability of light to penetrate into the water.

In well-mixed estuarial environments the tendency for maintaining sediment in suspension and thus obscuring light penetration appears to be somewhat offset by the fact that photosynthetic plants are also well-circulated in the water mass and thus may be brought into the photo-active zone frequently enough to insure a high level of activity.

Other quality constituents: Temperature, nutrients, and toxic compounds all represent important surveillance problems for estuaries.

Thermal wastes may tend to accentuate stratification of estuaries and in this way create special problems of waste assimilation. Large temperature differences can limit the availability of dilution water and the transfer

of oxygen and they can accelerate the demand on available oxygen resources.

Nutrients may hold the key to incipient eutrophication in estuaries and the consequent deterioration of quality for certain beneficial uses.

Toxic constituents have long been a problem in estuaries because of the proliferation of industrial sources in adjacent areas and because of the sensitivity of certain aquatic forms, particularly anadromous fishes, while they are temporarily resident in brackish estuarial waters.

d. Minimum Surveillance Requirements

The estuary represents the most formidable surveillance challenge among the various classes of water environments. It poses the maximum complexity in a hydrodynamic sense, with significant periodic and random motions upon which quality behavior closely depends. It may be stratified at times and well-mixed at others. It comprises a facultative transition zone between the fresh water vodies and the ocean, presenting to the aquatic community of plants and animals the widest range of living conditions. And it is the focal point of both natural and man-generated wastes, liquid and solid.

A minimum quality characterization program must consider:

1. type of quality constituent
2. size of estuary
3. shape of estuary
4. relation between runoff, tidal action and mixing potential (positive, negative, or neutral estuaries)
5. degree of stratification
6. quality, hydrologic, and hydrodynamic cycles
7. periodic vs. random phenomena

For the purposes of illustration there are developed herein and presented in Table II a set of recommended minimum data requirements for characterization of estuarial salinity.

Consider first the general configuration of the estuary; whether it may be described as one-dimensional, two-dimensional (either of type a or b) or three-dimensional. The problem of spatial characterization is magnified appreciably as the dimensional order is increased.

In a one-dimensional estuary the criteria for selection of number and spacing of stations need include only consideration of the length of the estuary, the annual range in salt penetration, and the requisite number of points needed to describe a salinity curve from salt to fresh water. It is recommended that the minimum number of stations for even the shortest estuary be at least four (one at the mouth, one at the limit of penetration, and two at the third-points). For longer one-dimensional estuaries the number may be increased, depending on the absolute length and to some degree on the ratio of maximum to minimum flow delivered through the estuary. There should be at least one station for each reach of estuary equivalent in length to the distance between the annual mean positions of the 30 to 70 percent sea water salinity levels. The uppermost station would be located at the upper limit of sea water penetration.

The number of samples required per station for the one-dimensional estuary would be the same as for a stream: two.

The minimum number of stations required for a two-dimensional stratified estuary would be the same as for the one-dimensional estuary; however, the minimum number of samples per station would be increased to four in the seaward one-third and to three in the central one-third.

A two-dimensional unstratified estuary--one which expands into an embayment--would need additional characterization in the wider zones. It is recommended that for all cross-sections normal to the estuary axis with a width to depth ratio greater than 100 at least three stations be employed, one at mid-channel and the others at the near-bank quarter points. Only a single mid-depth sample in support of the two mid-channel samples would be required at the two near-bank stations, a total of four per estuary section.

The spacing of stations required for three-dimensional estuaries would conform to the combined criteria for one- and two-dimensional estuaries.

The number of samples collected at near-bank stations would be reduced by one to 3 for the seaward third of the estuary, to 2 for the central third, and would be identical along the main estuary axis (4, 3, and 2, seaward to landward).

The frequency of sampling in an estuary depends on the quality period being characterized. Characterization of the diurnal tidal cycle, or a representative number of cycles, will probably produce the maximum useful information for the least effort in sampling. When several cycles are sampled, say during a dry weather period, they should normally be spaced about two weeks apart and when it is desired to characterize a complete annual cycle the minimum frequency should be about 6 per year.

In order to characterize quality phenomena in an estuarial environment on a diurnal basis, the optimum sample spacing is about two hours, or about six per tidal cycle ($\sim$ 12+ hours).

It must be appreciated that quality characterization of a complex estuary requires that sample collection be coordinated. The practice of collecting samples at "high slack water" simply because it roughly corresponds to maximum upstream penetration leaves much to be desired as a technique. It fails to consider the facts that: 1) high tide does not correspond to a condition of zero velocity, 2) in stratified estuaries all levels of the system at a point are not at rest at the same time, 3) slack conditions do not occur simultaneously over the estuary, and 4) slack water conditions are influenced by the state of runoff at the time of observation.

An acceptable procedure for quality characterization of estuaries which overcomes most of these objections is to undertake the continuous sampling over a complete tidal day (2 tidal cycles = diurnal cycle) of all stations and at all levels. This system does not require that samples be collected at all stations simultaneously, only continuously. Subsequent evaluation of quality patterns in space and time will yield the desired spatial distribution for a given point in time, probably the most useful quality information which can be obtained for an estuary.

An alternative method to that described above entails sequential sampling of all stations by the same team (all stations at one section continuously during a complete cycle) at least twice. The intervals between samplings of the same stations should embrace a common time for all stations. The state of the system at the common time can then be estimated by interpolation.

For investigations of the rate of change in quality constituents at a given station in an estuarial system, an appropriately spaced sequence of samplings is required. No less than three sets of observations for three adjacent sections should be used. Each should cover a complete diurnal cycle.

Table II is provided as a general guide to estimation of the number of stations, samples per station, and the frequency required to provide the minimum essential information for salinity characterization of an estuary. For other quality constituents the reader must make appropriate adjustments in spacing and frequency.

An interesting statistical analysis of sampling requirements for estuaries has been presented by Gunnerson (1966).

TABLE II

RECOMMENDED MINIMUM DATA REQUIREMENTS FOR
A SINGLE QUALITY CHARACTERIZATION OF AN ESTUARY OR EMBAYMENT---SALINITY

Class of Estuary	Degree Of Stratification	Q_{max}/Q_{min}	Number of Stations[1,2,3]	Samples Per Sta[4]	Frequency Per Cycle[5]	Observations Per Estuary[6]
One-dimensional	Fully mixed	< 10	≥ 4	2	6-12	48-96
		> 100	≤ 8	2	6-12	96-192
Two-dimensional	Fully mixed	< 10	$\geq 4+2$	2-4	6-12	60-120
		> 100	$\leq 8+4$	2-4	6-12	132-264
	Stratified	< 10	≥ 4	2-4	6-12	66-132
		> 100	≤ 8	2-4	6-12	144-288
Three-dimensional	Stratified	< 10	≥ 4	2-10	6-12	108-216
		> 100	≤ 8	2-10	6-12	288-576

[1] At least one for each reach = distance between annual mean positions of 30 and 70 percent seawater salinity.

[2] For two-dimensional estuaries add two supplementary stations when Width/depth ≥ 100.

[3] Locate supplementary stations at near-bank one-quarter points, sample at mid depth.

[4] Collect 4 samples at stations in seaward one-third of estuary, 3 samples in central one-third of estuary, and 2 samples in landward one-third.

[5] Six samples per tidal cycle (12 per diurnal cycle).

[6] This is for a one-day characterization. For an annual characterization, not less than six such one-day sets are needed.

Appendix D

PROPOSED ECOLOGICAL STUDY

Kachemak Bay

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
BOX 1668
JUNEAU, ALASKA, 99801

October 29, 1968

Mr. David G. Wagner
Research Engineer
Institute of Water Resources
University of Alaska
College, Alaska 99701

Dear Mr. Wagner:

This is in further reply to your letter of October 10 in which you requested information on Cook Inlet.

This Bureau's Auke Bay Biological Laboratory plans an intensified and comprehensive research program in the Kachemak Bay-Cook Inlet area beginning April 1969. The program will include chemical, physical, and biological oceanographic studies and biological and physiological studies on king crab and shrimp. The overall program will constitute an ecosystem research program with one of the prime objectives the acquisition of sufficient information to develop an ecosystem simulation model of Kachemak Bay and the adjacent Cook Inlet area.

Kachemak Bay and the adjoining small bays are highly valuable spawning and nursery areas for several important species of shellfish and finfish. One of the prime concerns of the Bureau of Commercial Fisheries is the effect of pollutants from upper Cook Inlet on these fishery resources. Our oceanographic studies will be designed to determine the vulnerability of the study area to pollution from Cook Inlet and to assess the consequences of pollutants on the resource organisms. The proposed study will extend over approximately a five year period.

The following research was conducted at Kasitsna Bay field station from 1963 to 1968:

Shrimp projects at Kasitsna Bay, 1963-1967:

1. Life histories of pandalid shrimp.

   Fairly complete sets of data on the life histories of Pandalus borealis and Pandalopsis dispar have been collected through year-round sampling at several locations in Kachemak Bay. Many aspects of the life histories of these species in Kachemak Bay are now known. Lesser amounts of data have been collected on the life histories of the other pandalids (Pandalus hypsinotus, Pandalus goniurus, and Pandalus platyceros) common in the area.

2. Ecology of pandalid shrimp.

   Some aspects of the ecology of pandalid shrimp have been studies for four years. Specifically, this project covered the species composition, and seasonal and annual changes in the composition and abundance of pandalid shrimp populations at several locations in Kachemak Bay.

3. Behavior of pandalid shrimp.

   Extensive work was conducted on the vertical distribution and diel vertical migration of P. borealis and other pandalid shrimp of Kachemak Bay.

4. Exploratory fishing for P. platyceros.

   Tutka Bay was systematically sampled to locate concentrations of spot shrimp, P. platyceros, to aid in future ecology and life history studies on this species.

5. Marking of pandalid shrimp.

   Experiments in marking of pandalid shrimp by staining, tagging, and clipping have been conducted at the Kasitsna Bay station. No field trials of any marks have yet been attempted.

Research projects conducted at Kasitsna Bay field station, 1967-1968:

1. Title: King crab fecundity study.

   Objective: To determine the number of eggs spawned and the number of eggs hatched and if significant mortality occurs during the ovigerous period.

   Results: King crab eggs were collected in May 1967 and January 1968. Additional sampling will be in May 1969. A report on the 1967 samples has been published.

2. Title: Pandalid shrimp fecundity study.

   Objective: Same as 1.

   Results: Shrimp eggs were collected in the spring of 1968 and are being collected at present. The samples collected in 1968 have been analyzed but no report written.

In addition to the limited research conducted by this Bureau in the Kachemak Bay area, a rather comprehensive investigation of king crab was conducted by University of California prior to 1960 under a Fish and Wildlife Service contract. The results of this investigation were published in 1960 under the title "King Crab Investigations of Cook Inlet, Alaska." You may obtain a copy of this publication from the Department of Biology, Allan Hancock Foundation, University of Southern California.

Exploratory fishing by the Bureau's Exploratory Fishing and Gear Research Base has been restricted in Cook Inlet to the waters south of a line drawn west from Anchor Point. The mission of our Exploratory Fishing unit is to define the seasonal distribution and abundance of the species concerned.

During 1961 and 1963, exploratory trawling was conducted in this area using both standard and west coast fish trawls (400 mesh eastern trawl) and Gulf of Mexico type shrimp trawls (40-foot flat shrimp trawl). Cruise reports for these surveys are attached.

The Bureau presently has no definite plans for additional exploratory work in upper Cook Inlet. Surveys planned for the next several years--on scallop, tanner crab, shrimp, and bottomfish--will undoubtedly include the waters of the lower inlet, perhaps as far north as Tuxedni Bay and Clam Gulch. No freshwater investigations are contemplated.

Enclosed please find the following publications:

Journal Fisheries Research Board of Canada, Vol. 24, No. 3, 1967
National Shellfisheries Association 1967 Proceedings
Special Scientific Report 560 "Surface-to-Bottom Pot Fishing for Pandalid Shrimp
Report of Cruise--Sept. 16-26, 1961
Report of Cruise--July 8-Sept. 11, 1963

We trust this information will assist you in the preparation of your report for the Federal Water Pollution Control Administration. If we can be of further assistance please contact us.

Sincerely yours,

H. L. Rietze

Harry L. Rietze
Regional Director

Enclosures: as cited (5)

Appendix E

WASTE DISCHARGE INVENTORY [24] and OIL SPILLS IN COOK INLET [FWPCA]

RANGE OF TEST VALUES FROM
SAMPLING PROGRAM

ANCHORAGE SEWERAGE STUDY

Sample Point	BOD mg/l		Total solids mg/l		Volatile solids mg/l		Suspended solids mg/l		Settleable solids ml/l		pH	
	low	high	low	high	low	high	low	high	low	high	low	high
City Pump Station Chester Creek	21	290	410	694	169	307	36	150	0.2	5.2	6.95	11.65
Manhole 21 Spenard	45	360	289	655	116	343	44	204	0.2	2.8	7.73	7.95
Elmendorf AFB & Government Hill	27	278	208	697	90	451	35	344	0.6	5.5	7.20	7.75
Ship Creek	9	116	284	446	104	298	11	170	0.05	1.5	6.85	7.61
Fort Richardson	64	332	208	664	105	500	31	440	0.5	7.5	7.15	8.05

STATISTICAL SUMMARY OF PUBLIC PLACES
POST EARTHQUAKE ENVIRONMENTAL HEALTH PROGRAM - 1966
Alaska Department of Health & Welfare
Division of Public Health

SEWER SYSTEM

NAME	Treatment					Effluent			
	Treatment Plant	Lagoon	None	Other Public Systems	Performance Records	Ocean or Inlet	Stream	Underground	System Not Adequate
State of Alaska Division of Aviation			x		x	x			x
City of Anchorage Water Utility			x		x	x			
Spenard Utilities Arctic Industrial				x					
Spenard Utilities Scenic Park		x							
Spenard Utilities State Manor #2									
Spenard District Service Area				x		x			
City of Palmer			x				x		
City of Kenai	x						x		
City of Seldovia			x				x		
City of Seward			x			x			

OIL SPILLS

FWPCA

PIPELINE SPILLS

1949 - 1 November 1968

Table 1.

Date	Location	Type of Spill	Cause	Magnitude
1966				
2/11	Riser at Shell "A"	Crude oil	Pipeline break	200 bbls
3/5	Riser at Shell "A"	Crude oil	Pipeline break	1200 - 1400 bbls
7/8	Between Pan Am "B" & Shell "A"	Crude oil	Pipeline leak	20 bbls
9/23	Between Shell "A" and E Foreland	Crude oil	Pipeline leak repair. Pulled bolt on manifold with anchor	50 bbls
12/13	Shell "A" - Forelands Area	Crude oil	Pipeline break	125 bbls
1967				
3/21	Forelands area	Crude oil	Pipeline leak	1 bbl/day
5/2	1 mi. East of Shell Platform "A"	Crude oil	Pipeline break repair	7 1/2 bbls on two shots to locate break
8/11	Forelands to Shell Platform "B"	Crude oil	Pipeline break	Less than 50 bbls (Reported by Shell)
1968				
6/6	Granite Point, Pipeline "B"	Crude oil	Pipeline break	380 bbls
10/23	Between Shell "A" & onshore	Crude oil	Pipeline break	1000 bbls

Table 2.

POLLUTION FROM PLATFORMS

1949 - 30 June 1968

Date	Platform & Location	Type of Spill	Cause	Magnitude
1962				
8/23	Pan Am test well N Cook Inlet	Crude oil & gas	Blowout well	Unknown. Considerable until torched.
1965				
1/65, 5/67	Pan Am MGS B	Engine oil	Crank case oil disposed	70 Gallons a week - 160 bbls total. Corrected 7/67
1966				
5	Pan Am MGS B	Oil	Drill steam test on platform	More than 50 bbls
7/10	Pan Am MGS B	Oil	Explosion	75 bbls
9/6	Shell A (MGS)	Oil	Probably diesel from mud	Emitting stream of oil, amount not given
9/23	Shell A (MGS)	Oil	Unknown	1 mi long, several hundred feet wide
10/10	Shell A (MGS), North of Platform	Oil	Unknown	Iridescent sheen and ropy masses
12/21	Pan Am "Anna", Granite Pt. area	Oil	Unknown	Brown stream several miles long. May have been drilling mud emission
12/21	Pan Am "Anna", Granite Pt. area	Mud sacks	Unknown	Mud sacks on ice for several miles
1967				
1/20	Pan Am "Anna", Granite Pt. area	Refuse	Person observed disposing refuse over side	Mud sacks and garbage

Table 2. (cont'd)

Date	Platform & Location	Type of Spill	Cause	Magnitude
1967 (cont'd)				
5/19	Pan Am "Bruce", Granite Pt. area	Oil	Discharge from platform	200 yards long
10/26	Shell C, Foreland area	Crude oil	Accidental valve mal-function	10 bbls
11/26	Unknown, below Forelands	Black oil	Drill stem test	90 bbls a day for 7 hrs.
1968				
1/19	Union-Marathom, Dolly Varden N of West Foreland	Oily substance	Drain pipe	Small sheen w/black mat'l
3/5	Unknown	Oil	Unknown	Not much
3/11	King Salmon, Trading Bay area	Oil	Unknown	1/2 bbl
3/28	Union monopod, Trading Bay	Oil	Wash tank	10 bbls
4/3	Pan Am "Dillon", East Foreland area	Diesel	Spill from welding machine	3600 yards long
4/5	Shell C, Middle Ground Shoal area	Oil	Possible diesel thru desander	5900 yds, 25-100 yds wide. Predominately sheen
4/7	Mobil, Granite Point area	Oil	Unknown	Heavy sheen w/black mat'l
4/11	Union Grayling, Trading Bay area	Oil	Tank Overflow	5 bbls
5/15	Mobil, Granite Point	Brown fluid w/sheen	Platform discharge line	Light sheen
5/15	At-Richfield, Trading Bay	(as above)	Platform discharge line	Light sheen

Table 2. (cont'd)

Date	Platform & Location	Type of Spill	Cause	Magnitude
1968 (cont'd)				
5/18	Pan Am, East Foreland area	Oil	Pipe flange leak	23 bbls
5/19	Pan Am, East Foreland area	Oil	Oil skimmer	2 bbls
5/19	Pan Am, "Dillon", East Foreland area	Oil	Pipe flange leak	12 bbls
5/26	At-Richfield, King Salmon, Trading Bay	Oil	Skimmer tank	3-4 bbls
6/13	Union Monopod, Trading Bay	Oil	Skimmer tank overflow	1/2 bbl
6/17	Shell C, Middle Ground Shoal area	Diesel in drilling mud	Mud pit overflow	Sheen 2 miles long
6/19	Union Grayling, Trading Bay	Oil Water	Skim tank overflow	1 bbl
6/22	Union Monopod, Trading Bay	Oil	Skim Tank overflow	1 bbl
6/24	Texaco-Superior A, Trading Bay	Engine Oil #30 & Polycomplex A-11	Barrel dumped by workmen	1 bbl

1949 - 30 June 1968

Table 3.

Date	Location	Type of Spill	Cause	Magnitude
1949				
10	Anchorage Port area - Sacketts Harbor vessel stern power plant	Oily ballast	Discharged fuel oil with ballast water	Possibly 30 bbls
1964 10/9	Anchorage Port area - Consolidated Freightways vehicle yard	Crank case oil	Oil dumped in servicing vehicles washed seaward	Reported "considerable"
1966 6/20	Nikiski, Rig Tenders Dock	Debris	Material dumped in leveling dock fill	Roots, limbs, trunks, dirt
7/11	Trading Bay, Pan Am road construction	Debris	Road construction	As above
1967 5/18	Port of Anchorage - Standard Oil facility	Oil	Broke gasket replacing blind spectacle on onshore line	Estimated 25 bbls
1968 1/2	Port of Anchorage - Texaco stge area	Av. gas	Drain pipe	1 bbl
2/28	Nikiski - Standard Oil Refinery outfall	Oil Sludge	Settling pond	3 ft. black glob at end of discharge pipe, slick along beach for 300 yards.
2/28	Nikiski - Kenai Pipeline Dock	Black oil	Sump pond	Small sheen around sump discharge
2/29	East Foreland area	Crude oil	Pig trap sump	2 bbls
4/15,16	Port of Anchorage - Army Dock	Black oil	Broken oil line	10-20 bbls
4/18	East Foreland area - Pan Am Shore facility	Crude oil	Oil clean-up trap	15 bbls

TANKER SPILLS

1949 - 30 June 1968

Table 4.

Date	Location & Vessel	Type of Spill	Cause	Magnitude
1966				
3/	Nikiski - Kenai Pipeline Dock	Stove oil	Tanker overflow	2,000 bbls
6/15,16	Nikiski Dock area	Oil	Leak in tank hole	1,000 bbls
1967				
5/2	Anchorage Port area - EVJE	Jet Spill	Tanker ruptured when it hit a reef near Fire Island	6,000 to 10,000 bbls
7/7	Nikishka - Tank Barge	Stove oil	Over pumping tank barge	Sheen on water
8/11	Nikiski - Kenai Pipeline Dock ATLANTIC ENGINEER	Ballast oil	Ballast pumped over-board	From oil dock to Colliers
11/12	Lower Cook Inlet & Kachemak Bay (Presumed a tanker involved)	Oil	Presumed tanker pumped m ballast overboard	Hundreds of oiled ducks, over 50 dead
12/30	Drift River - WASHINGTON TRADER	Crude oil	Vessel collided with dock & ruptured tank	1,500 - 1,700 bbls
1968				
5/4	Nikiski, Tanker ACHILLES	Crude oil	Unknown	2 bbls

POLLUTION FROM DRILL RIGS AND SERVICE BOATS

1949 - 30 June 1968

Table 5.

Date	Location & Vessel	Type of Spill	Cause	Magnitude
1966				
7/1	Drill Rig - Kalgin Island area	Refuse	Hunt Oil Co. vessel	Mud & cement sacks, visqueen & garbage
10/31	GLAMOR II - Near Nikiski	Oil	Heavy seas required dumping. Permission granted.	60 bbls
1967				
3/22	Moored vessel (drilling) in Seldovia Bay	Oil	Unknown	Oil all over bay, on boats & floats, ducks covered with oil.
3/23	WODECO II - Seldovia	Oil	Enginer oil & wipings	10 gallons
4/20	Drilling vessel - west side of Inlet	Refuse	Unknown	Several areas of refuse, mud sacks, & pallet boards
4/20	Drilling vessel - location not reported	Oil sheen	Unknown	Several areas
6/25	Drilling vessel - Trading Bay	Oil	Possibly in conjunction with Union monopod	2 miles long
7/5	Drilling vessel - Trading Bay #1	Oil	Hose on test barge loose	1 bbl
8/9	Derrick Barge - (Brown & Root) Cook Inlet	Oil	Unknown	2 mile slick from Port of Anch. to Pt. Woronzof
8/11	Jack-up rig - 1 mi. west of Nikishka	Oil	Moored rig	Small slick from rig
8/25	Barge - Granite Point	Oil	Barge alongside Mobil rig	Iridescent sheen; no estimate of size

POLLUTION FROM DRILL RIGS AND SERVICE BOATS
1949 - 30 June 1968

Table 5. (cont'd)

Date	Location & Vessel	Type of Spill	Cause	Magnitude
1967 (cont'd)				
9/19	Drill barge - Trading Bay, 4 mi. N of McArthur River	Oil	Unknown	Iridescent sheen from rig to beach. Waterfowl feeding in sheen.
9/27	Drill barge - Trading Bay, 4 mi N of Mc Arthur River	Oil	At-Richfield barge on beach	400 ft long, 100 ft wide at outer end
1968				
1/31	HERCULES, Tug - Seldovia	Diesel	Unknown	200 gal lost in mishap
3/31	CARL TIDE II - Rig Tenders Dock, Nikiski	Diesel	Unknown	110 gallons

Table 5a. FISHING VESSELS

1968				
1/19	ALEUTIAN QUEEN - Seldovia	Oil	Unknown	Around ship & into bay

POLLUTION INCIDENTS IN COOK INLET

1949 - 31 December 1968

Table 6.

Date	Location	Type	Source	Cause	Magnitude
1949 Oct	Anchorage Port area	Oily ballast	Shore facility Sacketts Harbor	Stern of sunken vessel used for city power, discharged poor grade fuel oil with ballast water	Possibly 30 bbls
1962 8/23	North Cook Inlet	Crude oil and gas	Platform Pan Am Test well	Blowout well	Unknown
1964 10/9	Anchorage Port area	Crank case oil	Shore facility Consolidated Freightways vehicle yard	Oil dumped in servicing vehicles washed seaward by rains	Reported as "considerable"
1965 1/65 5/67	Middle Ground Shoal area	Eng. Oil	Platform Pan Am MGS "B"	Crank case oil disposed	70 gallons a week - 160 bbls so far. Corrected 7/67
1966 3/5	MGS Platform "A" to East Foreland	Oil	Pipeline	Pipeline break between Shell platform A & East Foreland	50-100 bbls (ADFG reported 200 bbls from good source)
3/	Nikiski, Kenai Pipeline Dock	Stove oil	Vessel Standard Tanker	Tanker overflow	2,000 bbls
5/	Middle Ground Shoal area	Oil	Platform Pan Am MGS "B"	Drill stem test on platform	More than 50 bbls
6/	North Cook Inlet near Tyonek	Oil	Unknown	Unknown	Oil appearing substance on tide rips

Table 6. 1949 - 31 December 1968

Date	Location	Type	Source	Cause	Magnitude
1966 (cont'd)					
6/9	Salamatof Beach	Oil	Unknown	Unknown	Oil on beach. Two lines visible.
6/9	Moose Point area	Oil	Unknown	Unknown	Oil on water
6/15-16	Nikiski Dock area	Oil	Vessel Tanker	Leak in tank hole	1,000 bbls
6/19	North End Kalgin Island	Oil	Unknown	Unknown	Black gunky oil 3/4 mile long
6/20	Nikiski	Debris	Shore facility Rig Tenders Dock	Material dumped in leveling dock fill	Roots, limbs, trunks, dirt
6/19	Middle Ground Shoal area 2 mi NW Shell	Oil	Unknown	Unknown	Unknown
6/23	Near Glomar II and Western Offshore	Oil	Unknown	Unknown	Light slick with heavy black gunk in vicinity
6/24	From Kalifonsky Beach halfway to Kalgin Is.	Oil	Unknown	Unknown	10 miles long, 200-300 yards wide
7/1	Kalgin Island area	Refuse	Vessel Drill Rig	Hunt Oil Co. Drill rig	Mud and cement sacks, visqueen and garbage
7/8	Middle Ground Shoal Between Pan Am "B" & Shell A	Oil	Pipeline	Pipeline leak	20 bbls
7/10	Middle Ground Shoal area	Oil	Platform Pan Am "B"	Explosion	75 bbls
7/11	Trading Bay	Debris	Shore Facility	Pan Am road construction	Roots, limbs, trunks, and brush

POLLUTION INCIDENTS IN COOK INLET

1949 - 31 December 1968

Table 6.

Date	Location	Type	Source	Cause	Magnitude
1966 (cont'd)					
9/6	Middle Ground Shoal area	Oil	Platform Shell "A"	Probably diesel from mud	Emitting stream of oil, amount not given.
9/7	Unknown	Oil	Unknown	Unknown	Considerable oil surrounding platform
9/23	Middle Ground Shoal area	Oil	Platform Shell "A"	Unknown	1 mi long, several hundred feet wide
9/23	Between Shell A & East Foreland	Oil	Pipeline	Pipeline leak repair. Pulled bolt on manifold with anchor.	50 bbls
9/26	West Foreland area	Oil	Unknown	Unknown	Unknown
10/10	Middle Ground Shoal area N of Shell A	Oil	Platform Shell A	Unknown	Iridescent sheen and ropy masses
10/24	Between Pan Am B & Nikiski Dock	Oil	Unknown.	Unknown	Iridescent sheen and ropy masses 4 x 5 miles
10/25	East of Kalgin Is.	Oil	Unknown	Unknown	Iridescent sheen and ropy masses 1/2 x 1/4 mile
10/31	Near Nikiski	Oil	Vessel Glomar II	Pulled away from drill stem test. (Requested Permission to dump due to hazardous weather & sea conditions)	60 bbls
12/13	Forelands area	Oil	Pipeline Shell A	Break in Pipeline	700-1400 bbls
12/21	Granite Point area	Oil	Platform Pan Am Anna	Unknown	Brown stream several miles long. (May be drilling mud emission)

Table 6. 1949 - 31 December 1968

Date	Location	Type	Source	Cause	Magnitude
1966 (cont'd)					
12/21	Granite Point area	Mud sacks	Platform Pan Am Anna	Unknown	Mud sacks on ice for several miles
1967					
1/20	Granite Point area Pan American "Anna"	Refuse	Platform Pan Am Anna	Person observed throwing garbage from platform	Mud sacks and garbage
3/21	Forelands area	Oil	Pipeline Pan Am "B"	Pipeline leak	1 bbl a day
3/22	Seldovia	Oil	Vessel Drilling	Moored vessel	Oil all over bay, on boats and floats. Ducks covered with oil.
3/23	Seldovia	Oil	Vessel WODECO II	Engine oil and wipings	10 gallons
4/20	West side of Inlet	Refuse	Drilling vessel	Unknown	Several areas of refuse, mud sacks, and pallet boards
4/20	Not reported	Oil sheen	Drilling vessel	Unknown	Several areas
5/2	Port of Anchorage	Jet fuel	Tanker EVJE	Tanker hit reef west of Pt. Woronzof and ruptured	6,000 to 10,000 bbls
5/2	1 mile E of Shell Platform A	Oil	Pipeline Shell A	Pipeline break	7 1/2 bbls on two shots to locate break
5/8	South of Kalgin Is.	Oil	Unknown	Unknown	5 miles long by 20 yds wide
5/18	Port of Anchorage	Oil	Shore Facility Standard Oil	Broke gasket replacing blind spectacle on onshore line	25 bbls (est)

POLLUTION INCIDENTS IN COOK INLET

1949 - 31 December 1968

Table 6.

Date	Location	Type	Source	Cause	Magnitude
1967 (cont'd)					
5/19	Granite Point area	Oil	Platform Pan Am "Bruce"	Discharge from platform	200 yards long
5/19	North Cook Inlet	Oil	Unknown	Tyonek Creek	Along beach
6/19	Trading Bay	Unknown	Unknown	Unknown	Unknown
6/25	Trading Bay	Oil	Drilling vessel	Unknown, Possibly Union monopod	2 miles long
7/5	Trading Bay State #1 At-Richfield	Oil	Drilling vessel	Hose on test barge loose	1 bbl
7/7	Nikishka (Arness Dock)	Stove Oil	Tank Barge	Over pumping tank barge	Sheen on water
7/31	Nikishka to Boulder Point	Oil	Unknown	Unknown	Nikishka (Arness Dock) to Boulder Point
8/9	Port of Anchorage to Pt Woronzof	Oil	Derrick barge	From Brown & Root derrick barge	2 mile slick
8/11	Forelands to Shell Platform "B"	Oil	Pipeline Shell "B"	Pipeline break	Less than 50 bbls (reported by Shell)
8/11	Between Nikiski and Kalgin Island	Oil	Unknown	Unknown	2 slicks each 1 mi wide and 2 miles long
8/11	Nikiski, Kenai Pipe-line Dock	Oil	Tanker Atlantic Engineer	Ballast pumped over-board	From oil dock to Colliers
8/11	1 mi W of Arness Dock Nikishka	Oil	Vessel Jack-up rig	Rig moored	Small slick from rig

Table 6. 1949 - 31 December 1968

Date	Location	Type	Source	Cause	Magnitude
1967 (cont'd)					
8/11	Nikishka	Oil	Unknown	Unknown	Small Sheen
9/17	Nikiski	Oil	Unknown	Possibly from Kenai Pipeline Co. dock	Lots of black heavy oil
8/18	7 mi SW of Kenai	Oil	Unknown	Unknown	1/2 mi long by 2 mi wide; 3 mi offshore from Colliers dock when observed by FWPCA
8/25	Granite Point	Oil	Barge	Barge alongside Mobil Rig	Iridescent sheen; no estimate of size
9/19	Trading Bay 4 mi N of McArthur River	Oil	Drill barge At-Richfield	Unknown	Iridescent sheen from rig to beach, waterfowl feeding in oil sheen
9/20	Nikiski Docks to Kenai River	Oil	Unknown	Cause Unknown. Emission of white fluid from rig tenders dock noted.	1/2 x 3 mi and around vessels, oil observed near mouth of Kenai River
9/20	Nikishka, Arness dock	Oil	Unknown	Unknown	Large black globs & sheen in area of outer sunken vessel type dock.
9/27	Trading Bay, 4 mi N of McArthur River	Oil	Vessel Drill barge	At-Richfield barge on beach	400 ft long, 100 ft wide at outer end
9/27	1 m east of Pan Am B	Oil	Unknown	Unknown	3/4 mi long, 20 yd wide
9/27	Nikiski - Rig Tenders Dock	Oil	Unknown	Unknown	Around south side of dock
9/27	Nikiski - Rig Tenders Dock	Oil	Unknown	Unknown	From south side of dock 3 miles dock beach

POLLUTION INCIDENTS IN COOK INLET

1949 - 31 December 1968

Table 6.

Date	Location	Type	Source	Cause	Magnitude
1967 (cont'd)					
9/27	Nikishka - Arness Terminal	Oil	Unknown	Unknown	Sheen completely around facility
10/2	East Forelands between Shell C & Pan Am D	Oil	Unknown	Unknown	3 miles long with black ropy material
10/26	Forelands - Shell C	Crude Oil	Platform Shell C	Accidental Valve malfunction	10 bbls
11/22	Homer Beach	Black oil	Unknown	Presumed tanker ballast	4 oiled ducks
11/23	Anchor Point	" "	"	" " "	10-12 oiled ducks
11/24	Homer Beach	" "	"	" " "	Hundreds of oiled ducks
11/24	Ninilchik	" "	"	" " "	Several oiled ducks
11/25	Homer area	" "	"	" " "	43 dead ducks
11/30	Rabey Spit, Seldovia	" "	"	" " "	6 dead ducks
12/8	Halibut Cove	" "	"	" " "	2 sick cormorants, 1 sick loon, 7 dead ducks
11/26 27 28	Below Forelands	Black Oil	Platform	Drill stem test	90 bbls a day for 7 hrs
12/6	Between Forelands & Rig Tenders Dock	Black oil	Unknown	Unknown	200 by 400 yards
12/7	1 1/2 mi W of Nikishka	Black oil	Unknown	Unknown	Small amount of black oil
12/21	East Foreland area	OIl	Unknown	Possible diesel from drilling mud	(1) 1/2 m x 200 feet (2) 100 x 100 yards
12/21	Nikiski	Oil	Unknown	Unknown	3 m long & 1/4 m wide
12/30	Drift River Terminal	Crude Oil	Tanker Washington Trader	Vessel collided with dock & ruptured oil tank	1500-1700 bbls

POLLUTION INCIDENTS IN COOK INLET

Table 6. 1949 - 31 December 1968

Date	Location	Type	Source	Cause	Magnitude
1968					
1/2	Port of Anchorage	Av. gas	Texaco stge area	Drain pipe	1 bbl
1/3	Southeast of Kalgin Island	Brown dis-colored water	Unknown	Unknown	Several strings
1/8	128° & 20 m from E Chugach Light	Black oil	Unknown	Unknown (probably tanker ballast)	50-75 ft wide, several miles long
1/19	North of W Foreland	Oily appear-ing substance	Union-Marathon Dolly Varden	Drain pipe	Small sheen w/black material
1/19	Seldovia Bay	Oil	Vessel Aleutain Queen	Unknown	Around ship & out into bay
1/26	Nikiski near Rig Tenders Dock	Black oil	Unknown	Unknown	Black globs on ice passed dock for 3 hrs.; 20 to 30 ft wide; 30 to 40 ft off-shore
1/31	Seldovia	Diesel	Tug HERCULES	Unknown	200 gal lost in mishap
2/18	Seldovia - Homer	Oil	Rebecca	Pumping ballast	20 mile slick
2/28	Nikiski	Oil sludge	Standard Oil Refinery outfall	Settling pond	3 ft black glob at end of discharge pipe, slick along beach for 300 yds
2/28	Nikiski	Balck oil	Kenai Pipeline Dock	Sump pond	Small sheen around sump discharge
2/29	East Foreland area	Crude oil	Shell onshore	Pie trap sump	2 bbls
3/5	Platform area	Oil	Platform Unknown	Unknown	Not much

POLLUTION INCIDENTS IN COOK INLET

1949 - 31 December 1968

Table 6.

Date	Location	Type	Source	Cause	Magnitude
1968 (cont'd)					
3/11	Trading Bay	Oil	Platform "K"	Unknown	1/2 bbl
3/12	Trading Bay, near King Salmon platform	Oil	Unknown	Unknown	1/2 bbl
3/26	Trading Bay, near King Salmon platform	Refuse	Unknown	Unknown	5 pallet boards & several mud sacks
3/28	Trading Bay	Oil	Platform Union Monopod	Wash tank	10 bbls
3/31	Nikiski Rig Tenders Dock	Diesel	CARL TIDE II	Unknown	110 gallons
4/3	E Foreland Pan Am Dillon area	Diesel	Platform Pan Am Dillon	Spill from welding machine	3600 yards long
4/4	Salamatof Beach to Kenai River mouth	Oil	Unknown	Unknown	5 mi long, 100 yd wide
4/5	Middle Ground Shoal area	Oil	Platform Shell "C"	Possible diesel thru desander	5900 yds, 25-100 yds wide Predominately sheen
4/7	Seldovia Bay	Oil sheen	Unknown	Unknown	East side of Seldovia Bay to entrance
4/7	Granite Point	Oil	Platform Mobil	Unknown	Heavy sheen w/black material on it
4/11	Trading Bay area	Oil	Platform Greyling	Tank overflow	5 bbls
4/15 16	Port of Anchorage	Black Oil	Old Army Dock	Broken oil line	10-20 bbls

POLLUTION INCIDENTS IN COOK INLET

Table 6. 1949 - 31 December 1968

Date	Location	Type	Source	Cause	Magnitude
1968 (cont'd)					
4/17	Grayling Platform	Diesel	Vessel Tug Crowley	Broken hose	315 bbls
4/18	East Foreland area	Crude oil	Pan Am shore facility	Oil clean-up tank	15 bbls
5/4	Nikiski Kenai Oil Dock	Crude Oil	Tanker ACHILLES	Unknown	2 bbls
5/10	Trading Bay, 3 mi W of monopod	Oil	Unknown	Unknown	1 square mile of sheen
5/15	Granite Point	Brown fluid with sheen	Platform Mobil	Platform discharge line	Light sheen
5/15	Trading Bay	Brown fluid with sheen	Platform At-Richfield King Salmon	Platform discharge line	Light sheen
5/15	Trading Bay, 1/4 m S of Grayling Platform	Oil	Unknown	Unknown	2 squre mi sheen
5/18	East Foreland area	Oil	Platform Pan Am Dillon	Pipe flange leak	23 bbls
5/19	East Foreland area	Oil	Platform Pan Am Dillon	Pipe flange leak	12 bbls
5/19	East Foreland area	Oil	Platform Pan Am Dillon	Oil skimmer	2 bbls
5/26	Trading Bay	Oil	Platform At-Richfield King Salmon	Skimmer tank	3-4 bbls

POLLUTION INCIDENTS IN COOK INLET

1949 - 31 December 1968

Table 6.

Date	Location	Type	Source	Cause	Magnitude
1968 (cont'd)					
5/29	Nikiski S of Kenai Pipeline dock	Oil	Unknown	Unknown	50 ft wide, 1 mi long
6/6	Granite Point, 3 mi E of "Bruce"	Crude oil	Pipeline "B" line	Pipeline break	380 bbls
6/13	Trading Bay	Oil	Platform Union Monopod	Skim tank overflow	1/2 bbl
6/17	Middle Ground Shoal area	Diesel in drilling mud	Platform Shell "C"	Mud pit overflow	Sheen 2 miles long
6/17	Granite Point area	Oil	Pan Am Platform Bruce	Broken seals in crane motor	3 gallons
6/17	Granite Point area	Lube Oil	Pan Am Platform Anna	Plugged oil skim tank pump	1 bbl
6/19	Trading Bay	Oily water	Platform Union Grayling	Skim tank overflow	1 bbl
6/22	Trading Bay	Oil	Platform Union Monopod	Skim tank overflow	1 bbl
6/24	Trading Bay, Texaco	Engine oil #30 & Poly-Complex A-11	Platform Texaco - Superior A	Barrel dumped by workmen	1 bbl
7/2	Port of Anchorage	Garbage & debris	Unknown	Unknown	Unknown
7/17	Trading Bay area	Oil	Platform Union Grayling	Debris stuck pump in waste water tank	2 bbls

POLLUTION INCIDENTS IN COOK INLET

Table 6. 1949 - 31 December 1968

Date	Location	Type	Source	Cause	Magnitude
1968 (cont'd)					
7/22	Seward	Oil	Mermaid II	Cooling system malfunction	Unknown
8/3	Granite Point area	Oil	Platform Mobil	Unknown	Light sheen
8/3	Between Platform Mobil & Union Monopod	Oil	Unknown	Unknown	Small oil globs in tide rips
8/3	Middle Ground Shoal	Oil	Platform Pan Am "B"	Unknown	Crescent shapped sheen, vicinity of platform
8/13	Trading Bay area	Oil	Platform Union Grayling	Overflow on floatation tank	2 bbls; 1 mi long, 1/2 mi wide
8/15	Rig Tenders Dock	Cement	Carl Tide II	Dumped by crew	unknown
8/17	Between Union Platforms Monopod & Grayling	Oil	Unknown	Unknown	100" X 300"
8/17	Minicipal Dock,Homer	Fish waste & debris	Alaska Seafoods	Dumping	Unknown
8/20	Port of Anchorage POL Dock	Black oil	Unknown	Unknown	Less than 1 bbl
8/27	1/2 m N of Monopod	Oil mat'l	Unknown	Unknown	10 x 40 yds
8/27	Between Dillon and Shell "A"	Oil	Unknown	Unknown	1/2 mi long, 5 mi wide
9/5	Ship Creek & Port of Anchorage	Oil	Oil storage tank, City Public Works	Tank or truck leak	100 bbls
9/6	Marathon "Dolly Varden"	Oil	Collection reservoir	Clogged drain	1 bbl

POLLUTION INCIDENTS IN COOK INLET

1949 - 31 December 1968

Table 6.

Date	Location	Type	Source	Cause	Magnitude
1968 (cont'd)					
9/9	1/2 mi E of Union "Grayling"	Oil	Unknown	Unknown	1 mile long
9/10	1 mi below Woronzof to Port of Anchorage	Oil	Tanker PANOS	Unknown	1 1/2 mi long, 1/2 mi wide
9/12	Marathon "Dolly Varden"	Oil	Skim tank	Failure of high level switch gear	3 bbls
9/30	Pan Am "Dillon"	Oily bitum-inous mat'l	Drilling mud	Mud out of balance	Unknown
9/30	Below "Dillon"	Garbage	Unknown	---	Evident
9/30	Phillips	Garbage	Platform	Unknown	Evident
10/4	Anchor Point area	Oiled Guillemots	Unknown	Possibly tanker discharge	200 waterfowl
10/20	2 mi NE of "Anna"	Oil	Pan Am "Bruce"	Kobe tank overflow	35 bbls
10/20	Same as above in oil slick	Garbage	Unknown	---	Evident
10/23	Shell pipeline "B" 1/2 to shore faci-lity from Platform A	Oil	Pipeline "B"	Pipe failure	1000 bbls
10/28	E of Kalgin Island	Oil	Possibly from Shell pipe failure	Unknown	Large amounts mixed with tide tip debris
10/30	Pan Am "Dillon"	Diesel oil	Dillon	Broken valve	2 bbls
10/30	Same as above	Oily mat'l	Heliport	Unknown, mixed with snow	Unknown

Table 6. 1949 - 31 December 1968

Date	Location	Type	Source	Cause	Magnitude
1968 (cont'd)					
10/30	Same as above	Garbage	Dillon	Man throwing overboard	Evident
10/30	Nikiski Oil Dock	Gasoline	Tanker HANNA	Discharge clean wash water after contamination	Unknown volume, 2 mi long 300 yd wide
10/30	2 mi E of Union onshore	Oil	Unknown	Unknown	2 mi long, 300 yd wide
10/31	Union "Monopod"	Oil	Skim tank	Overflow	10 gallons
11/6	Union "Grayling"	Oil	Slop tank	Overflow	5 bbls
11/7	Texaco-Superior	Oil	Separator tank	High level switch failure	5 bbls
11/12	Nikiski Oil Dock	Oil	Tanker HOuston	Unknown	Unknown
12/6	Anchor Point	Oil	Unknown	Unknown	4 miles along beach
12/17	Marathon Dolly Varden	Oil	Skim Tank	Pump Clogged	10 bbls

Appendix F

SPECIAL STUDIES, COLLIER CARBON AND CHEMICAL CO.

[ALASKA DEPARTMENT OF HEALTH & WELFARE]

To: All Alaska Newspapers and Radio Stations
From: Alaska Department of Health and Welfare

Juneau, March 25, 1968 -- Collier Carbon and Chemical Corporation plans to begin continuous sampling at all of its 11 initial effluent monitoring sites in Cook Inlet in April, according to a report made by the company at the request of the Department of Health and Welfare. Early samplings prior to plant start-up will establish normal base-lines for comparison after operations begin. It defines the "oceanographic and biological studies that will be made in 1968 and 1969 to assure the safety of Cook Inlet biota (flora and fauna)". The detailed plans submitted are currently under review by Amos J. Alter of the Office of Research and Academic Coordination, Department of Health and Welfare. The plant's first product will be ammonia, utilizing natural gas available from the oil industry of the area.

The new series of routine and continuous studies, the Collier company's letter stated, will augment information from its 1967 studies reported last October to the state Departments of Health and Welfare and Fish and Game, and to the Federal Water Pollution Control Administration.

Cooperating with the Collier Corporation in the monitoring studies, in addition to the Department of Health and Welfare and Fish and Game, will be the University of Alaska Institute of Marine Science, and University of Washington personnel.

The corporation has recently posted a $100,000 performance bond in consonance with the conditions of the temporary permit issued by the Department of Health and Welfare.

Statement of the Bureau of Commercial Fisheries, U.S. Department of the Interior, presented by Melvin A. Monson, Regional Fish and Wildlife Administrator, on November 6, 1967, at the Soldotna meeting, regarding the application by Collier Carbon and Chemical Corporation for a permit to discharge effluent from their proposed ammonia-urea fertilizer plant into the waters of Cook Inlet.

At the request of the Alaska Water Laboratory, Federal Water Pollution Control Administration, Fairbanks, Alaska, the U.S. Bureau of Commercial Fisheries reviewed the application for proposed development and by letter dated April 17, 1967, submitted its comments and recommendations to the Federal Water Pollution Control Administration. In the interim, the applicant made certain studies on the effect of the effluent discharge on the highly important fish and other marine resources of Cook Inlet. Their findings are contained in a report dated October 13, 1967, to the State of Alaska, Department of Health and Welfare. The Bureau of Commercial Fisheries has not had the opportunity to review in detail the results of the study. However, from a cursory examination, we believe that certain phases of the investigations are not of sufficient depth to permit an evaluation of the full impact the effluent will have on fish and other marine resources of the Inlet.

The position of the Bureau of Commercial Fisheries on the project remains the same as stated in our letter of April 17. We believe that it is the responsibility of the applicant to conduct pre- and post-operational bio-environmental studies to determine conclusively whether or not the effluent would adversely affect the fish and other marine resources or alter the ecology of the Inlet. The burden of establishing these facts should rest primarily with the applicant. Such studies should be carried out during the planning and operational

stages in cooperation with interested State and Federal agencies so that these agencies can make available research results and technical data to assist the company in solving the pollution problem. We believe this is an achievable goal.

In view of the importance of the resources invovled, it is imperative that every possible effort be made to protect them. We again recommend that any permit issued for this project include the following conditions requiring Collier Carbon and Chemical Corporation to:

1. Cooperate with the Alaska Department of Fish and Game, Federal Water Pollution Control Administration, U.S. Fish and Wildlife Service, and other interested Stated and Federal agencies in developing plans for pre- and post-operational bio-environmental surveys.

2. Conduct, or bear the cost of conducting, pre-operational bio-environmental studies of the cook Inlet area that would be affected by the effluent. These surveys should include, but not be limited to, the distribution, abundance, and seasonal cycles of invertebrates, vertebrates, and phytoplankton; the collection of data on the physical environment to establish the gross circulation and water movement and flushing time; and surveys to determine the reaction of anadromous species (juvenilles and adults) to the introduction of effluent. These survey should be carried out in the field by knowledgeable fish and wildlife Scientists.

3. Prepare a detailed report on the results of the pre-operational bio-environmental surveys and submit it to the above mentioned agencies prior to project operation. Make such changes in project construction and operation as may be required as the result of these findings.

4. Conduct post-operational bio-environmental surveys similar to those specified in recommendations 1 and 2,assess any changes in flora, fauna, or physical environment as a result of project operation, analyze data, and prepare and submit reports every 3 months during the first year the project is in operation and every 6 months thereafter, or until it has been conclusively demonstrated that the effluent does not adversely affect the resources.

5. Design the plant in such a manner to provide for subsequent installation of facilities to recover ammonia wastes and make such further modification in project structure and operation as may be required.

Thank you for the opportunity to present this brief statement. Our detailed comments and recommendations are contained in our letter to the Federal Water Pollution Control Administration dated April 17, 1967.

November 6, 1967

Statement of the Federal Water Pollution Control Administration presented by Mr. E.K. Day, Director, Alaska Water Laboratory on November 6, 1967, at public presentation of studies by Collier Carbon and Chemical Corporation at Soldotna, Alaska.

The position of the Federal Water Pollution Control Administration, Alaska Water Laboratory, regarding the application from Collier Carbon and Chemical Corporation for a waste discharge permit has not changed. Reference is made to my letter of June 6 to Gov. Hickel and to the letter of April 17, 1967, from Mr. John Hodges, Acting Regional Director, Bureau of Commercial Fisheries, Juneau, Alaska (copies attached). A copy of Mr. Hodges' letter was made available to the State Department of Health and Welfare.

Recommendations of the Federal Water Pollution Control Administration, Alaska Water Laboratory, are as follows:

1. Collier Carbon and Chemical Corporation be required, through modification of plant process or waste treatment, to reduce the ammonia content of the effluent discharged into Cook Inlet to a practical minimum.

2. Studies as recommended by the U.S. Bureau of Commercial Fisheries be made a condition of any permit issued.

It has been the practice in the past to design waste treatment facilities to utilize the total assimilative capacity of receiving waters. This has proven to be a short sighted practice which has led to many of the water pollution problems in other areas. This has resulted in a need for pollution abatement at a cost far greater than the cost of prevention.

The present national policy is to reduce the amount of waste discharged to receiving waters to the practical minimum. Adherence to this policy will provide for the greatest beneficial use of the water resources and provide for a maximum future development.

Industry should be expected to spend a reasonable percentage of plant cost to enhance water quality or to protect it to the greatest degree possible for all beneficial uses. The average home owner pays in the order of 5% of the cost of his home for sewage collection and treatment.

Circumstances did not permit a detailed staff review of the reports on toxicity and oceanographic studies. Preliminary examination of the report indicates that additional studies should be made in greater depth including seasonal conditions.

The Federal Water Pollution Control ADministration, Alaska Water Laboratory, appreciates the opportunity to participate in these discussions.

Appendix G

COMPUTER PROGRAMMING LANGUAGES and SERVICE ORGANIZATIONS

APPENDIX D-1

PROGRAMMING LANGUATES

Various implementation levels of the following languages are now in common use. It is expected that one of these will be selected as the standard language for the data management system.

ALGOL (Algorithmic-Oriented Language) An international procedure-oriented language.

COBOL (Common Business-Oriented Language) A Computer language used in business-oriented data processing.

FORTRAN (Formula Translator) An IBM-developed procedure-oriented language.

PL/1 (Programming Language One) A new high level procedure-oriented language designed to meet the needs of both business and scientific applications.

APPENDIX D-2

COMPUTER SERVICE ORGANIZATIONS

1.	Auerbach Corporation	1634 Arch Street Philadelphia, Pennsylvania
2.	Computer Consultants	445 Cambridge Avenue Palo Alto, California
3.	Computer Science Corporation	650 North Sepulveda Boulevard El Segundo, California
4.	Computer Usage Co. Inc.	655 Madison Avenue New York, N.Y.
5.	Data Corporation	4050 Wilshire Boulevard Los Angeles, California
6.	Data Systems Analysts, Inc.	5900 Westfield Avenue Pennsauken, New Jersey
7.	Information Sciences Associates	110 Wynwood Avenue Cherry Hill, New Jersey
8.	Information Systems Company	1111 Wilshire Boulevard Los Angeles, California
9.	Melonics System Development Division of Litton Industries	1001 West Maude Avenue Sunnyvale, California
10.	Service Bureau Corporation	1493 Park Avenue San Jose, California
11.	System Analysis, Inc.	1000 Acacia Avenue Los Altos, California

Appendix H

SAMPLING EQUIPMENT AND METHODS and ANALYTICAL PROCEDURES

REFERENCES DEALING WITH SAMPLING EQUIPMENT AND METHODS, AND ANALYTICAL PROCEDURES

Text or Reference	Publisher	Remarks
Hydrographic and Hydrologic		
Others (5,6,30,31,37,38,89,138,157,162,168, 175,211)		See Reference List for details
Geologic		
The Oceans - Their Physics, Chemistry, and General Biology (177)	Prentice Hall	Excellent coverage of equipment and methods - somewhat dated.
Methods for Tracing Estuarial Sediment Transport Processes (99)	University of California	
Others (174, 5, 6, 37, 162, 174, 209)		See Reference List for details
Physical and Chemical		
The Oceans - Their Physics, Chemistry, and General Biology (177)	Prentice Hall	Excellent coverage of equipment and methods - somewhat dated.
Final Report - A Comprehensive Study of San Francisco Bay, Vol. 1, Physical, Chemical, and Biological Sampling and Analytical Methods (80)	University of California	Describes work recently completed
Marine Chemistry, Vol. I and II	Marcel Dekker, Inc.	
Others (5, 6, 37, 88, 151, 174)		See Reference List for details
Biological		
The Oceans - Their Physics, Chemistry, and General Biology (177)	Prentice Hall	See previous note

REFERENCES DEALING WITH SAMPLING EQUIPMENT AND METHODS, AND ANALYTICAL PROCEDURES

Text or Reference	Publisher	Remarks
Final Report - A Comprehensive Study of San Francisco Bay, Vol II, Biological Sampling and Analytical Methods (166)	University of California	See previous note
Others (5, 6, 53, 65, 148, 151, 174, 188, 212)		See Reference List for details
Pollution Studies		
Tracer Studies and Pollutional Analyses of Estuaries (169)	University of California	Description of typical study
Torrey Canyon, Pollution and Marine Life (171)	Cambridge University Press	Oil pollution and its effects
Others (5, 149, 174, 184)		See Reference List for details