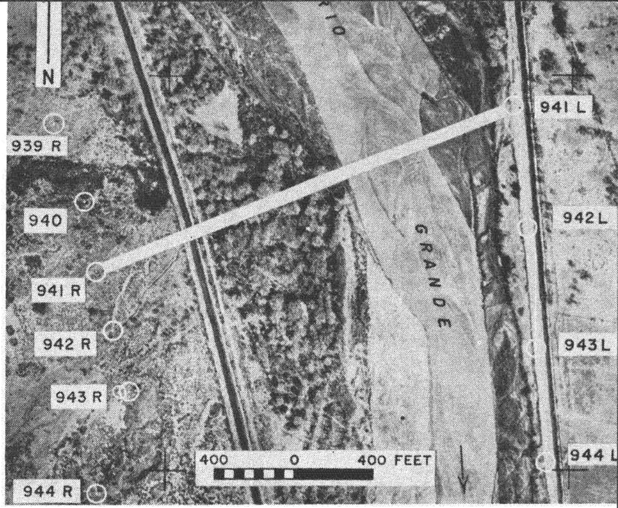
Photogrammetry and photointerpretation are applied extensively by the Bureau of Reclamation in planning and maintaining irrigation development. The photograph illustrates the type of sedimentation information obtained by aerial survey methods by showing a part of the valley of the Rio Grande. Numerals show ends of range lines along which terrain profiles were obtained by photogrammetric methods. The solid white line indicates the location of the profile shown in Figure 8, the arrow identifying the direction of stream flow.



Resource Understanding —A Challenge to Aerial Methods

Aerial methods are needed to assist in cadastral surveys, National Parks, water resources, geologic mapping and ocean surveys.

STEWART L. UDALL
Secretary of the Interior
Washington, D. C.

(*Abstract on next page*)

INTRODUCTION

THE nation's expanding population and the increasing demands of industry are shortening the time it has in which to acquire the basic knowledge for providing its present and future citizens with the resources and recreational facilities they will need. These resource needs are staggering: for example, it now uses water at a rate equivalent to 118 trillion gallons a year, and this rate is currently increasing by approximately 25 thousand gallons *per minute*. The future needs are almost beyond comprehension. Persons now living will need approximately 6,000 trillion gallons of water and 90 million tons of copper in their lifetime, yet the known reserves of copper are only about 40 million tons! In fact, the total amounts of natural resources needed by the people now living in the United States are larger than the totals used previously by all mankind.

The knowledge needed to provide and manage these resources and to guide development of the national lands is obtained through many kinds of surveys. The nation maps its lands topographically and geologically, assess its wildlife, surveys the seas to increase its production of marine resources (food, fuel, and minerals), conducts the cadastral and other detailed surveys of its lands, and appraises its water resources.

Because topographic maps are a basic part of almost all of the national resource investigations, the need for accelerated production of these maps was recognized earlier than the need for some related types of surveys. Scientists reacted to this need and developed aerial mapping methods that have since resulted in vastly increased production of topographic maps having a high degree of precision. Twenty short years ago, only 27% of the nation was topographically mapped in a form adequate to meet today's needs. Today, 69% of the nation is adequately mapped, a total of some two (2) million square miles.

Map makers are continuing to refine the techniques of topographic mapping with the the result that the annual production of these maps is steadily increasing (Figure 1) and, equally important, that the man-years of effort required to map a square mile of our nation is consistently diminishing (Figure 2). Continuing research in the methods of photogrammetry and other techniques relevant to the mapping program will unquestionably result in greater precision, larger production, and lower cost.

The development of the aerial methods by which these maps are made provides an excellent example of the ability of the scientific community to respond to a national need. The record clearly shows the advantages of aerial methods in terms of cost and speed in contrast to ground methods that have been historically employed.

It is the purpose of this paper to call attention to some of the ways in which aerial techniques are being applied in other survey fields. Hopefully, the scientific community will be encouraged to refine these methods further so that their use may be increased and the veracity of data improved.

Aerial Surveys of Our National Lands

Aerial surveys assist the planners in developing lands now held by expediting their subdivision, helping appraise their present and potential uses, and assisting determination of fair prices for mineral and other leases. These surveys likewise help guide the procurement of lands and scenic rights that will provide the recreational facilities for present and future generations, and assist in preserving in the national parks a measure of our nation's heritage.

Abstract: *Aerial survey methods are speeding acquisition of survey data needed to provide and manage the nation's resources. These methods have been applied to topographic mapping for a number of years and the record clearly shows their advantages in terms of cost and speed in contrast to the ground methods that have been historically employed. Limited use is now being made of aerial methods to assist cadastral surveys, in location, acquisition and development of National Parks, in mapping the geology of the nation, in locating and developing water resources, and in surveys of the oceans. It is the purpose of this paper to call attention to these uses and to encourage the scientific community to further refine aerial methods so that their use may be increased and the veracity of data improved.*

The Bureau of Land Management has the responsibility for determining the boundaries of National Lands and for subdividing them for future development. As the settlement of new lands in this country progressed, the best agricultural land, being in the greatest demand, was surveyed first. The land that remains is mostly difficult of access and rugged in nature. The character of the land is such that the cost of surveys, by conventional ground methods, are very high. To expedite development of these lands and to combat rising costs, our Bureau of Land Management is applying photogrammetry increasingly in their cadastral surveys and has demonstrated the advantages of aerial methods. Surveys of this type combine photogrammetric and field survey methods. These "combined" methods permit the full utilization of existing field geodetic control and the establishment of supplemental geodetic control from aerial photographs. The use of photographs to determine the approximate positions of corner locations adds greatly to the economy of employing some new airborne survey instruments such as the hoversight. These uses

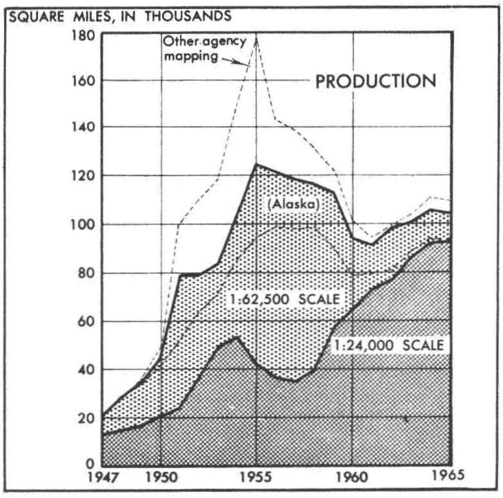


Fig. 1. Annual production history of topographic maps.

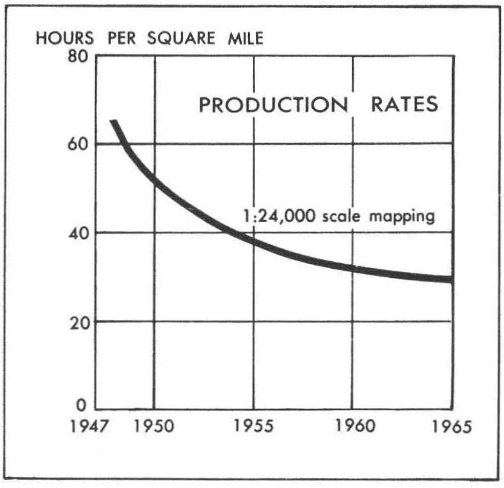


Fig. 2. Production rate history for topographic mapping.

are still experimental but the use of photographs for surveying meandering bodies of water and in studies of range vegetation, timber cover and access to public lands, are now routine.

An important mission of the National Park Service—identification and investigation of potential park sites—has been made more systematic, dependable, expeditious and economical by the use of aerial photographs.

An example, which best illustrates the importance of aerial photographs in proposed park work, is the true prairie study conducted in 1959. Here a primary criterion was to consider grasslands of at least 30,000 acres that were largely free of manmade changes such as cropland, roads, and buildings. In just five days aerial index maps of large portions of the Dakotas, Nebraska, Kansas, Oklahoma and Texas were screened. Only 24 sites of sufficient size were disclosed within the whole of this immense area; these 24 sites were then studied on the ground. The time and expense saved in reducing the prairie park possibilities to 24, by using photographs, was most economical compared to ground or aerial reconnaissance of this same area.

In a recent application of airphoto analysis, the Bureau of Outdoor Recreation and the National Park Service were able to obtain valuable information for use in evaluating Assateague Island, Maryland (Figure 3) for national seashore purposes. Comparison of airphotos, taken before and immediately after the storm of March 1962, provided data indicating that acquisition of the area for public recreation use would be appropriate since private resort development would be very hazardous.

In other appraisals of recreation potential, airphoto analysis provided information about quality of forest cover, shoreline condition, size of proposed areas, and other information in the evaluation of the Allagash River, Maine, the Pictured Rocks area, Michigan, and Fire Island, New York. Photographs such as that shown in Figure 4 play a very important role in conveying information to those responsible for finalizing our programs. These photographs enable wise and complete planning, with full knowledge of the terrain, existing installations, and the surroundings.

Once lands are acquired, aerial methods continue to be used in the planning, development, improvement, and use-assessment of these holdings. Figure 5 is a mosaic of aerial photographs illustrating some of the aspects of national park and parkways planning that can either be performed by photointerpretation or facilitated by such studies. Following planning, photogrammetry plays a major role in the development of these lands, particularly in route selection and design of roads and parkways.

The National Lands contain valuable mineral resources, and the Federal Government leases many of these lands for exploration and development. The terms of leases,

FIG. 3. Photograph of a part of Assateague Island after the storm of March 1962. Superimposed lines show approximate property lines as surveyed prior to the storm of March 1962.

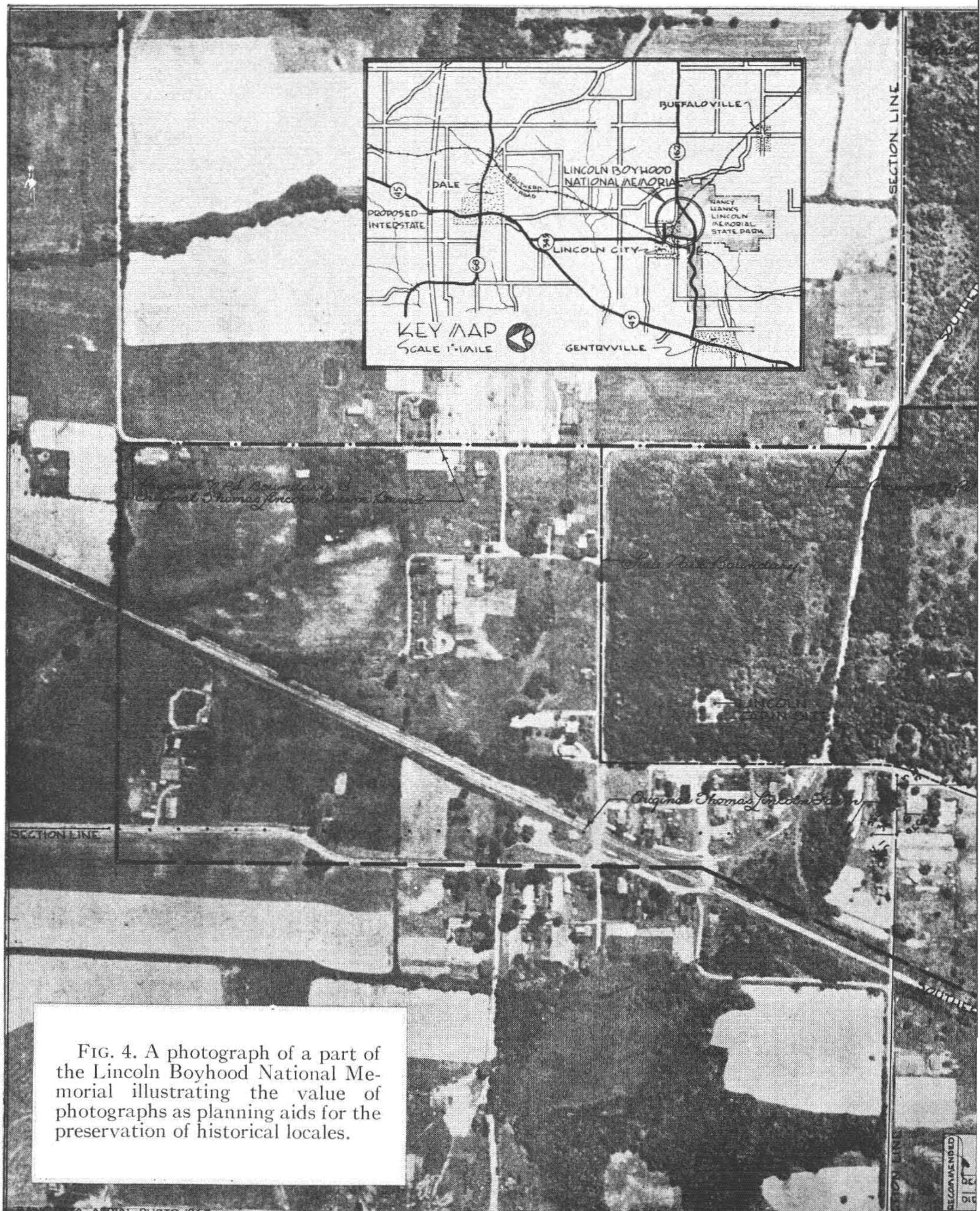
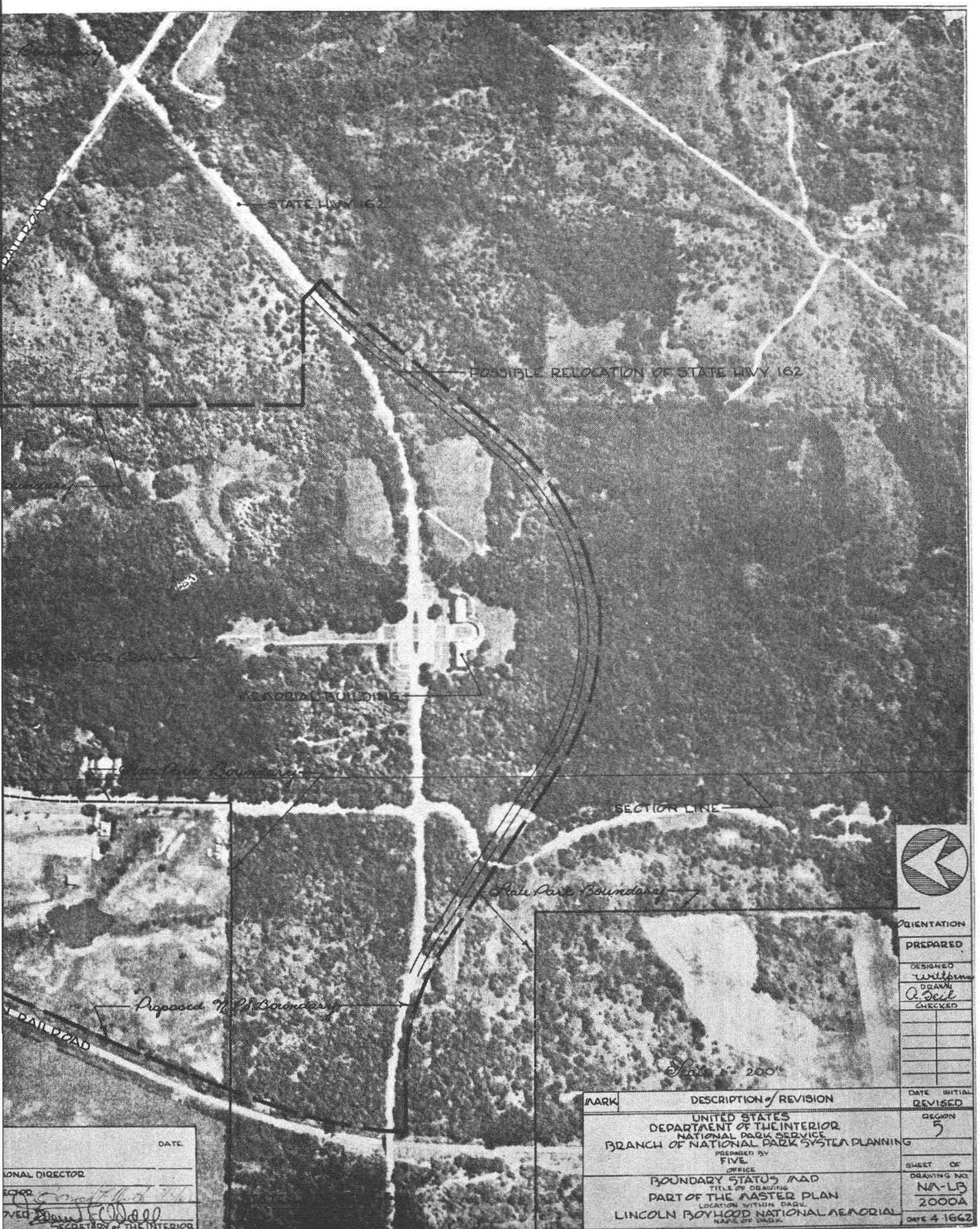


FIG. 4. A photograph of a part of the Lincoln Boyhood National Memorial illustrating the value of photographs as planning aids for the preservation of historical locales.


STATE HWY 162
POSSIBLE RELOCATION OF STATE HWY 162
MEMORIAL BUILDING
SECTION LINE
State Park Boundary
Proposed N.P.S. Boundary
RAILROAD
ORIENTATION
PREPARED
DESIGNED
DRAWN
CHECKED
Scale 1" = 200'
MARK
DESCRIPTION of REVISION
DATE INITIAL
REVISED
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
BRANCH OF NATIONAL PARK SYSTEM PLANNING
PREPARED BY
FIVE
OFFICE
REGION
5
SHEET OF
BOUNDARY STATUS MAP
TITLE OF DRAWING
PART OF THE MASTER PLAN
LOCATION WITHIN PARK
LINCOLN BOYHOOD NATIONAL MEMORIAL
NAME OF PARK
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NM-LB
2000A
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DATE
DIRECTOR
SECRETARY of THE INTERIOR

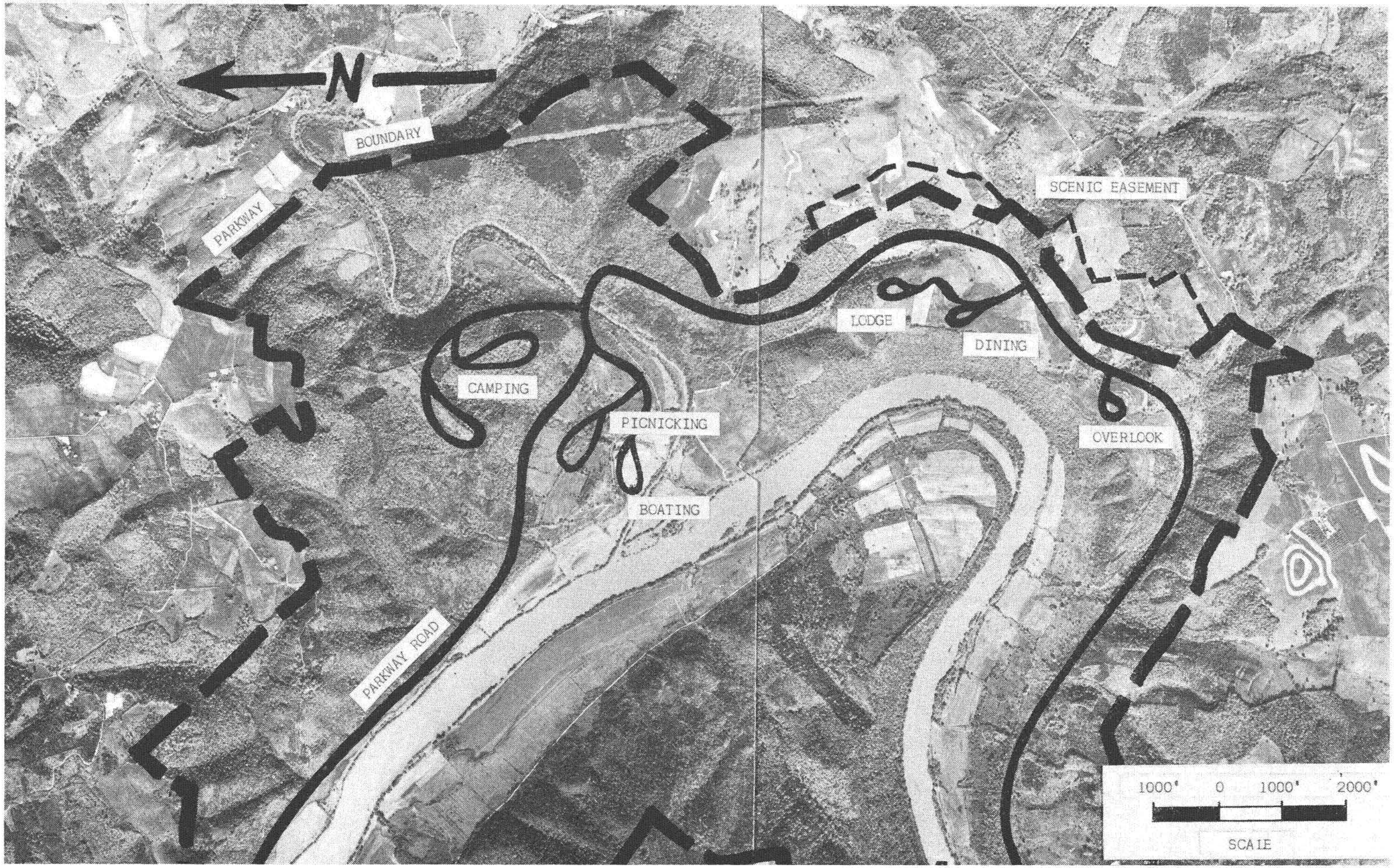


FIG. 5. A mosaic of aerial photographs showing a part of a proposed parkway development and illustrating some of the service, recreation, and scenic aspects of parkway planning that are facilitated by the interpretation of aerial photographs.

including remuneration to the government, depend in large part on the state of geologic knowledge of the areas in question. The geologic investigations of northern Alaska by our Geological Survey forms an excellent example of the benefits that can accrue to the citizens of this country from geologic studies that make use of aerial survey techniques. Northern Alaska is difficult of access and expensive to explore. Photogeologic studies were used to guide ground exploration and, on occasion, exploration drilling. These studies resulted in the delineation of the axes of over 100 closed anticlines which may be favorable structures for the accumulation of oil and gas.

Included among the structures, whose full extent was first mapped by interpretation of aerial photographs, was the Gubik anticline. The early photogeologic map of this structure is shown in Figure 6. Subsequent drilling of this structure revealed substantial quantities of natural gas and indications of the presence of petroleum. This structure has now been leased to private industry for further exploration and, hopefully, for development. The return to our Treasury was almost a half-million dollars, many times the cost of the photogeologic studies. More importantly, natural gas from this structure may well provide a significant part of the energy required for future development of this or other parts of Alaska.

The Department of Interior's water-resources investigations are designed to gain information about water as it occurs in its natural and man-modified environment in and on the earth. The Geological Survey has the unique role in the Nation's water investigations of providing the fund of basic information upon which nearly all water development in the United States is based. The Survey data needed to fulfill this obligation include facts concerning location, quantity, quality, movement, and mode of occurrence of the water resources of the Nation. Because of growing need for water resources, a high priority is placed on the collection of these data. Aerial survey methods are being applied in the collection of some data relating to water resources, for example, in mapping the distribution of phreatophytes (plants that depend on ground water) (Figure 7) and in measuring the volume of snow packs, particularly in the mountains of the western United States. This latter measurement is made by photographing large targets, comprising a vertical pole with horizontal crosspieces spaced at regular intervals, that are placed in selected tracts of watershed. Observation of these photographs provides a measure of depth of burial of the vertical poles and hence the thickness of the snow cover.

It is incumbent upon the Nation to utilize the water resources it has so as to yield the most benefit. To accomplish this aim the Bureau of Reclamation makes large use of photogrammetry and photointerpretation in appraisals of lands relating to suitability for irrigation development and in the planning of irrigation developments. Fundamental to these studies are large scale topographic maps produced by photogrammetric methods. Once established, the irrigation systems must be maintained; maintenance is made difficult in some areas by the rapidity with which natural drainage channels change both in location and sedimentation. Observation of these changes enables us to take corrective steps as required. The photograph on the title page and Figure 8 illustrate the type of sedimentation information obtained by aerial survey methods and the significant changes that take place in some stream channels in relatively short lengths of time.

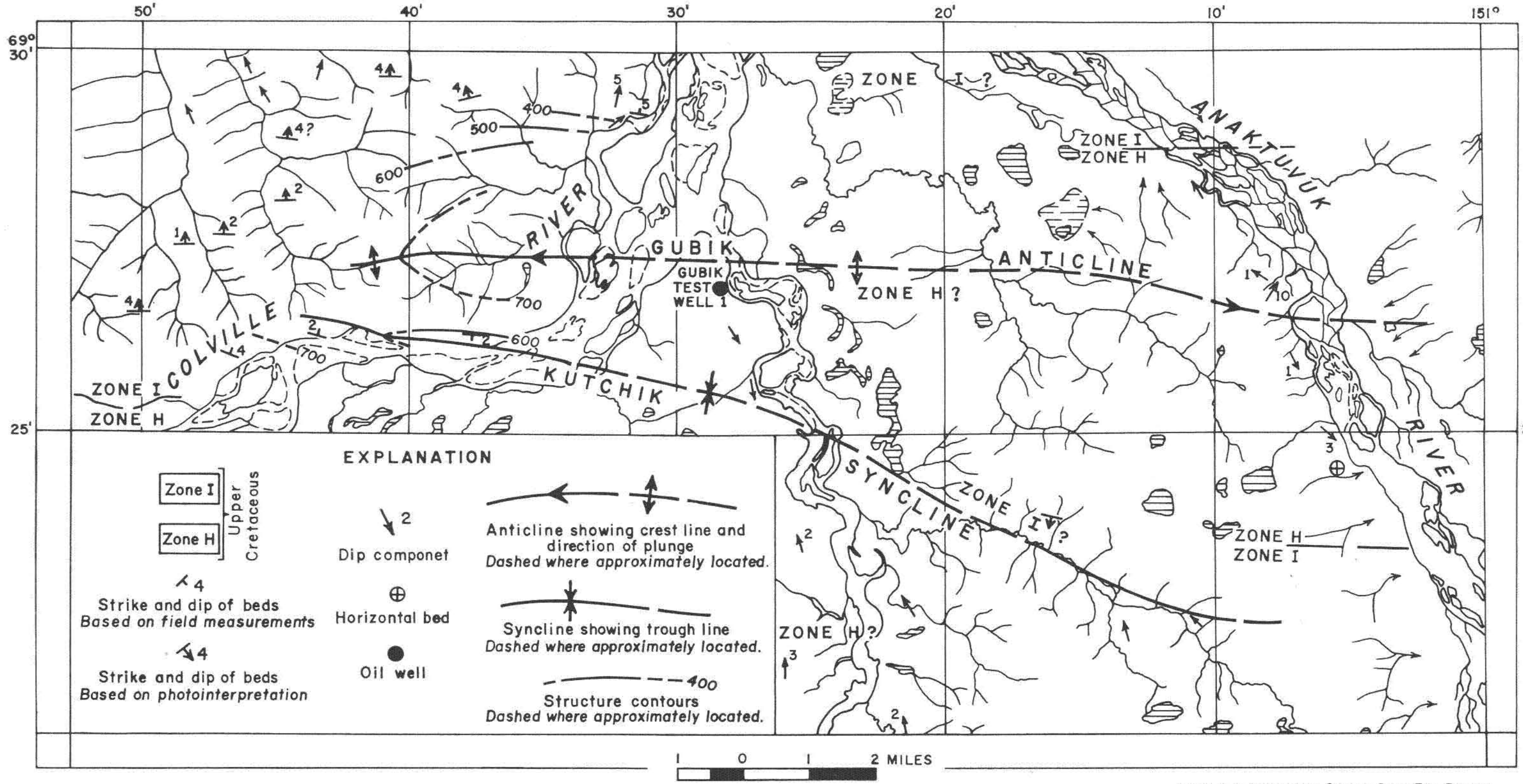
Preliminary selection of damsites and hydrologic observation stations, as well as detailed topographic maps of site locations, are made from aerial photographs. It has been found, however, that with the present state of knowledge, later ground geologic and engineering studies are absolutely essential to final site selection.

It is believed that additional benefits can accrue to the hydrologist in the use of aerial photographs and are undertaking relevant research so that these benefits will be more completely realized. Universities are also encouraged to include courses in photo interpretation in their hydrology curricula.

Aerial Surveys of the Seas

Large-scale studies of the marine environment require that data be collected over vast expanses of the sea. Because of the high cost of operating research ships, collection of some data is now underway by the Fish and Wildlife Service with streamlined aerial survey techniques. One such technique is the use of the recently developed infrared thermometer to measure sea surface temperatures.

Periodic aerial surveys of sea surface temperature fields were initiated in 1962, by the Sandy Hook Marine Laboratory of our Bureau of Sport Fisheries and Wildlife, in cooperation with the U. S. Coast Guard. The survey program was designed to provide



From U.S. Geological Survey Open File Report

FIG. 6. Photogeologic map showing a part of northern Alaska including the axes of the Gubik anticline and the Kutchik syncline.

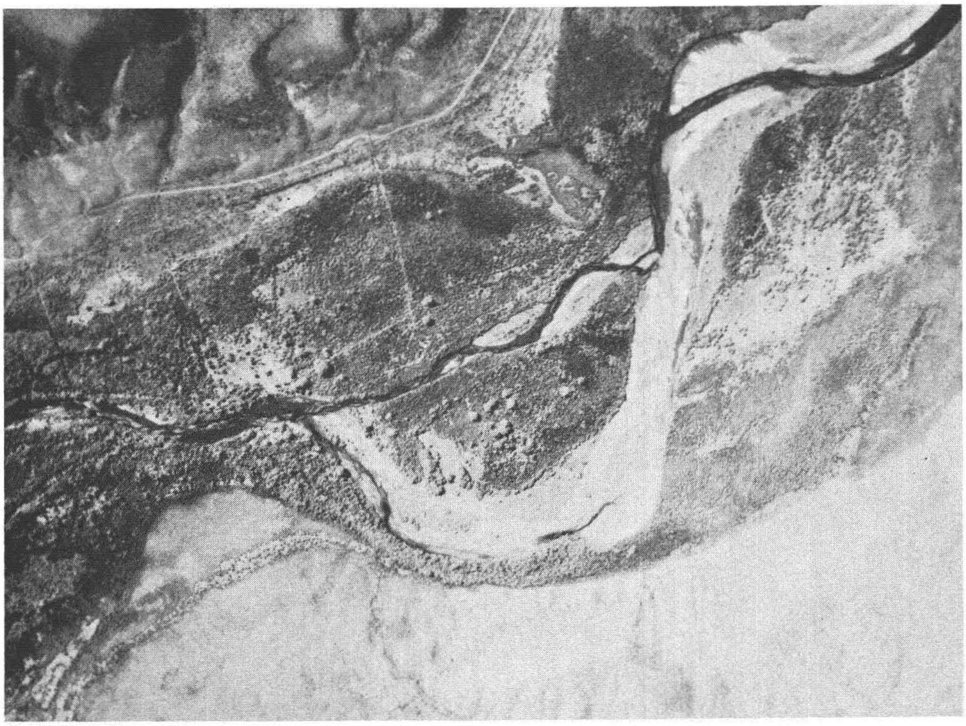


FIG. 7. Infrared photograph of a part of the Gila River Valley, Arizona, showing the distribution of phreatophytes (water-loving plants).

nearly simultaneous temperatures of Atlantic coastal waters over an area of approximately 16,000 square miles. Within three days of completion of each month's survey, the isotherm charts (Figure 9) are duplicated and distributed to all interested persons and agencies.

Once a complete series of monthly sea surface temperature maps are available for a number of years, Bureau biologists hope to be

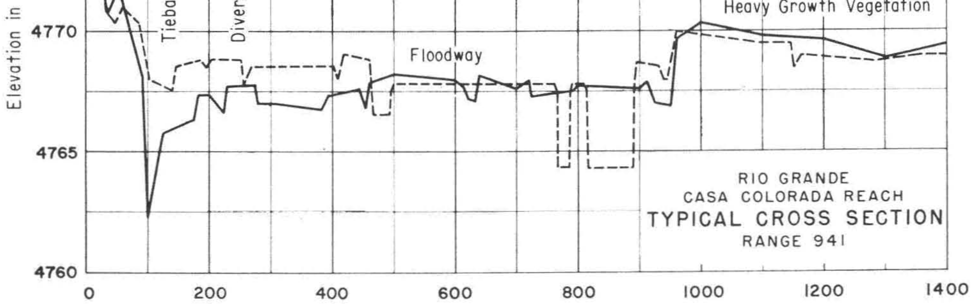


FIG. 8. Terrain profiles along range line 941 shown in the photograph on the title page; solid line as surveyed in March 1955, dashed line as surveyed in February–March 1962.

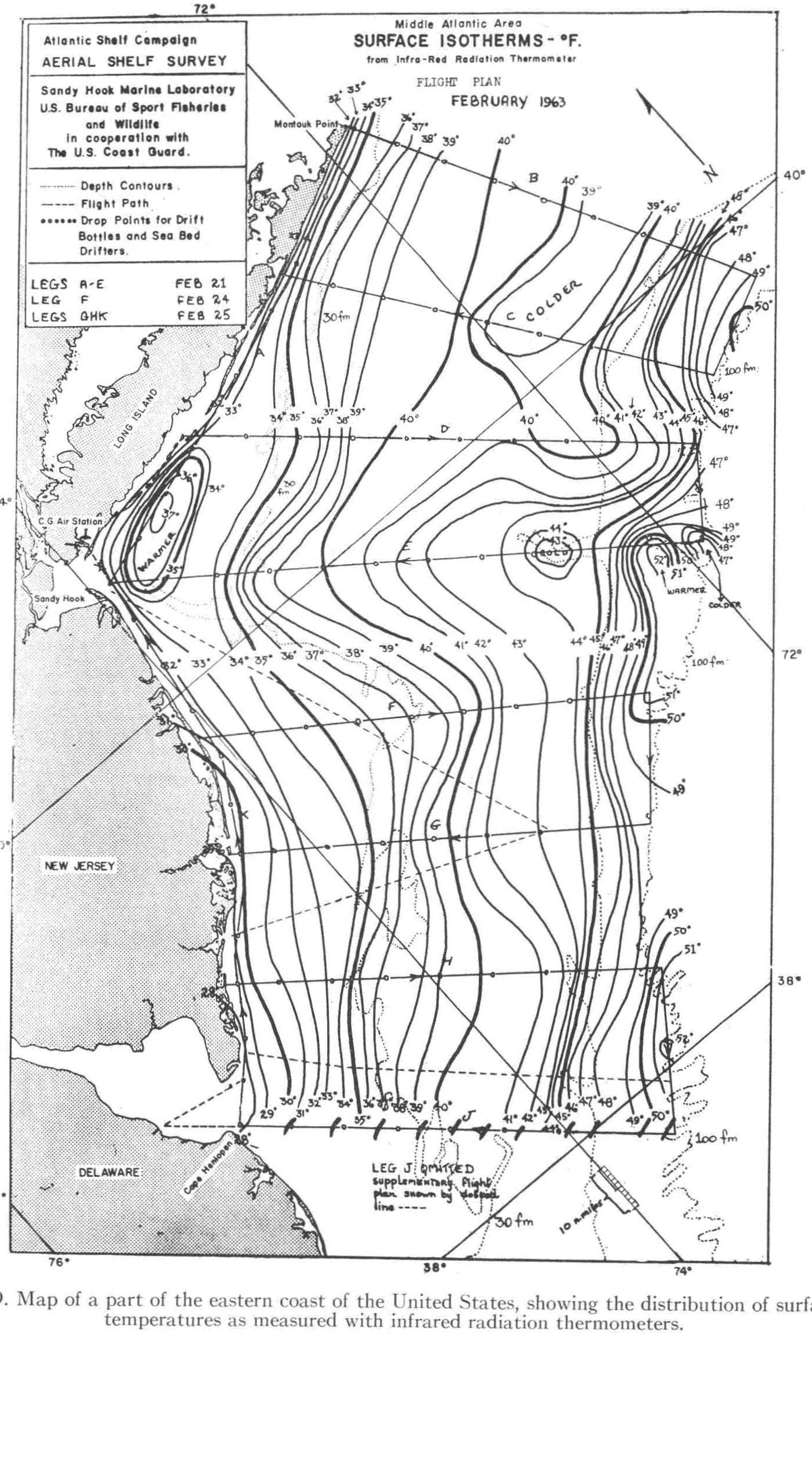


FIG. 9. Map of a part of the eastern coast of the United States, showing the distribution of surface temperatures as measured with infrared radiation thermometers.

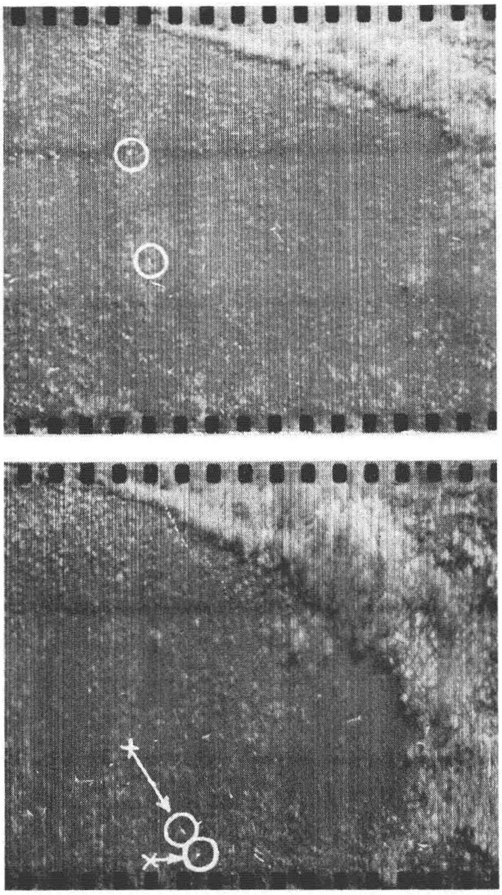


FIG. 10. Infrared images of moose on Isle Royal, Michigan. Lines on lower image show movement of moose during interval between coverages. *Courtesy of RADC-USAF.*

able to predict the effect of seasonal changes or long term cycles in ocean temperatures on important fish stocks, such as mackerel, bluefish, and tuna.

In addition to the temperature recordings, sea-bottom and sea-surface drift indicators are dropped into the water every 10 miles during the flights. By tracking the drift paths of indicators which are found and returned by boatmen and beachcomers, it is possible to measure ocean currents. It appears hopeful that a technique can be worked out to deduce the currents directly from temperature maps once the relationships are determined.

A Look to the Future

Aerial photographs are now being supplemented by images recording invisible parts of the electromagnetic spectrum, such as the infrared. The tone with which objects are recorded on these new infrared images is largely dependent on the temperatures of objects in the field of view.

Wildlife are protected from their enemies by natural camouflage. This same camouflage makes it extremely difficult to assess and properly manage this resource. Wild animals, however, contrast strongly with the land and forest in their temperature, and preliminary experiments (Figure 10) suggest that they can be inventoried by means of infrared images.

Aerial infrared measurements and images now provide direct information relating to the distribution of thermal energy on the surface of the earth. Figure 11 is a conventional photograph of Kilauea volcano on the island of Hawaii. Figure 12 is an infrared image of

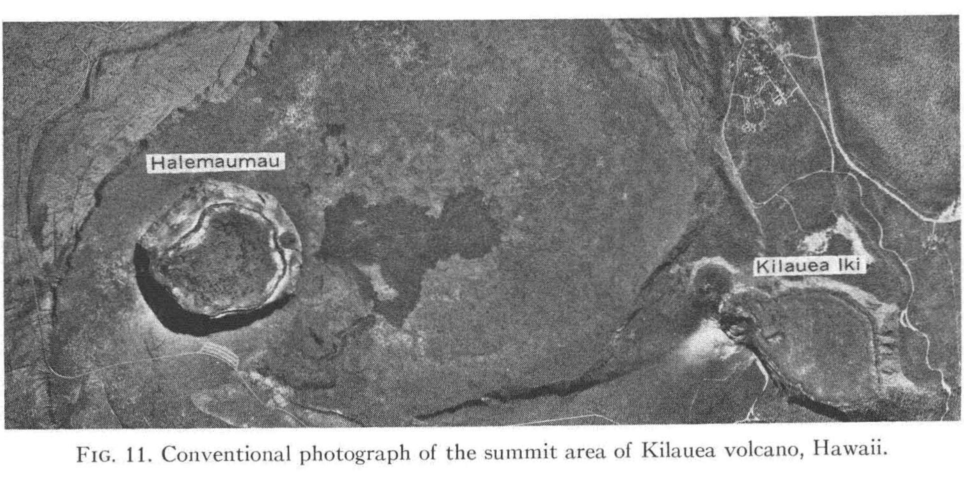


FIG. 11. Conventional photograph of the summit area of Kilauea volcano, Hawaii.

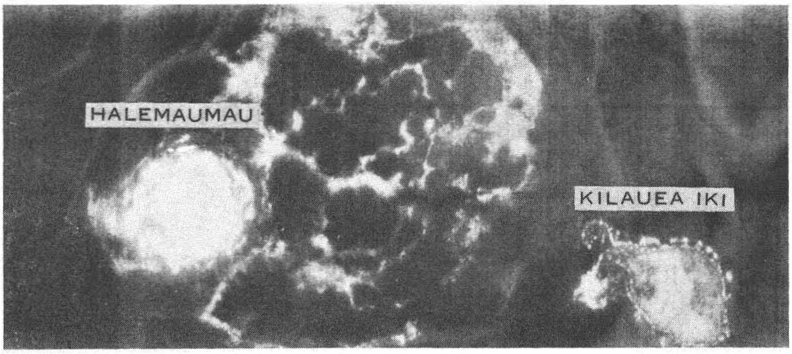


FIG. 12. Infrared image of the same area shown in Fig. 11. Light toned areas are those that are warmed by volcanic processes.

approximately the same area. The light tones on the infrared image represent areas that are warmed by volcanic processes. Images such as these are enabling our Geological Survey to understand better the volcanic processes and the tectonic effects associated with them. These observations suggest that some eruptions may be preceded by observable thermal anomalies and give some hope that man may be able to forsee some cataclysmic events that now take lives and destroy property. The Geological Survey is likewise applying these new infrared imaging techniques to its search for adequate water resources. Figure 13 is a conventional photograph of the waterfront at Hilo, Hawaii. Figure 14 is an infrared image of the same area. Note that on the infrared image, relatively cool streams of water can be seen issuing into the relatively warm water of the sea. There are few streams on the island of Hawaii; most rainfall percolates through the highly permeable rock and migrates outward to be discharged into the ocean near the periphery of the island. Infrared surveys have enabled the geologists to locate over 200 spring discharges around the coastline of the island of Hawaii, many on the arid west coast. Likely, these supplies of fresh water will aid in the future development of this part of the island.

Figure 15 is a radar image showing a part of central New Mexico. This image clearly illustrates a correspondence between geologic features and strength of radar return. Igneous rocks, for example, show with bright images in contrast to most sedimentary rocks and soils, which show with darker tones; structural features, including anticlinical structures (classic locations for deposits of oil and gas), are likewise visible. Of especial importance, however, is the fact that images of this type record the surface of our nation at rates

FIG. 13. Conventional aerial photograph of the waterfront area in Hilo, Hawaii.

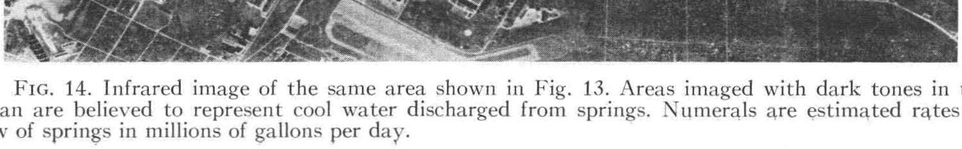
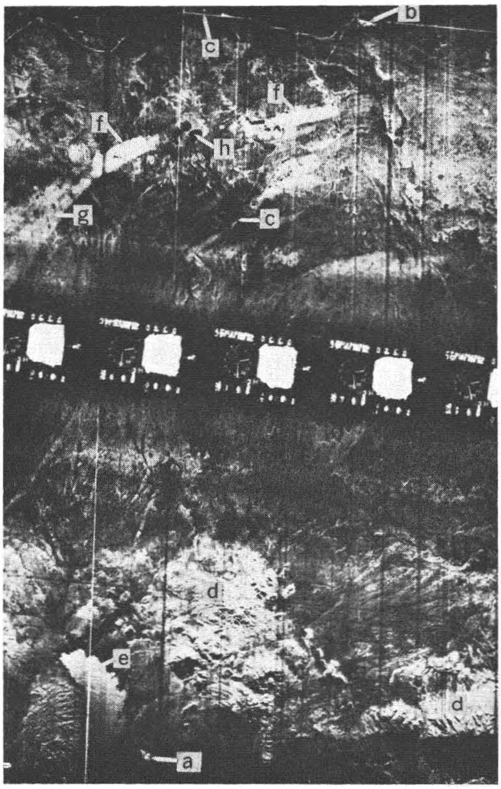


FIG. 14. Infrared image of the same area shown in Fig. 13. Areas imaged with dark tones in the ocean are believed to represent cool water discharged from springs. Numerals are estimated rates of flow of springs in millions of gallons per day.



of more than 50,000 square miles per hour. Man has much to learn about the interactions of radar and other forms of electromagnetic energy with natural objects before we can make full use of these types of information. Hopefully, research programs will soon make it possible to use data such as these in routine manner for our lasting benefit.

Research and testing of these methods should not only be conducted to fulfill current needs but future needs must also be recognized in advance. Judging from the past, the demand for data will be far greater than now. More rapid means of accumulation and of interpretation of these data must be and can be developed by our ambitious and imaginative scientific and engineering programs. The Nation needs to redouble its efforts to meet the foreseeable challenges.

FIG. 15. Radar photograph of a part of east-central New Mexico. a) city of Carrizozo, b) city of Vaughn, c) railroads, d) areas underlain by intrusive igneous rocks, e) basalt flow, f) areas of drifting sand, g) fields plowed some years before image was produced, and h) evaporite deposits in floor of playa lake. Areas imaged with medium and dark grey tones are largely underlain by rocks of sedimentary origin. *Courtesy Corps of Engineers*

KEYNOTE SPEAKER 1965 ASP-ACSM CONVENTION

Mr. James E. Webb, appointed Administrator for the National Aeronautics and Space Administration by President Kennedy in February 1961, has agreed to make the keynote speech to the 1965 ASP-ACSM Convention, to be held at the Shoreham Hotel, Washington, D.C. March 28–April 3, 1965. An attorney and businessman, Mr. Webb has held several high positions in government and industry; among them, Director of the Bureau of the Budget, Undersecretary of State, Board of Directors, McDonnell Aircraft and Kerr-McGee Oil Companies. Mr. Webb studied law at George Washington University and holds a commission in the Marine Corps Reserve. Honorary degrees have been awarded to Mr. Webb by the universities of North Carolina, Syracuse, George Washington, Notre Dame, Washington University (St. Louis), Kansas City, Northeastern (Boston), Oklahoma City, and Pittsburgh and Colorado College. It is an honor to both our Societies that Mr. Webb has consented to take time from his busy schedule to address our Conventions. (*See announcement of convention on page 44.*)