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U.S. DEPARTMENT OF COMMERCE
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Dr. Robert M. White, Administrator
Howard W. Pollock, Deputy Administrator
Dr. John W. Townsend, Jr., Associate Administrator

APRIL 1972
VOLUME 2 NUMBER 2

Page

3. A Message From the Administrator
4. Alaska's Problem Rivers—*by Edwin P. Weigel*
14. Crystal Ball for the Bay—*by James J. Napoli*
19. Dust Devil—*by Jack R. Cooley*
22. As the Oceans Rise—*by Steacy D. Hicks*
25. Fish Cities—*by Ann Weeks*
30. Warning! Avalanche Weather—*by William T. Chapman and Frank Reanier*
34. Small Boats on the Great Lakes—*by John Hanna*
39. Mr. Geodesy—*by Raymond Wilcove*
42. Reach Into the Sea—*by Leon La Porte*
44. This Round Earth—*by Philip M. Cohen*
48. Fingerprinting the Funnel—*by Joann Temple Dennett*
52. The Great March Storm
55. A Wealth of Fish
58. News from NOAA

COVER

On the Great Lakes, spring heralds the opening of the boating season. For NOAA's research laboratories, the season brings intensified observation of tornadoes and other severe storms. On the front cover, sailboats await the start of the annual Mackinac race. On the back cover, the 30-foot antenna of the National Severe Storms Laboratory's Doppler radar.

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A Message From the Administrator

ROBERT M. WHITE

President Nixon's budget, now before the Congress, lays out an exciting program of new and expanded activity for our organization for the year ahead.

We do not know what action Congress will take on our request for funds to carry out these new programs, but it is a measure of the important role the Administration has assigned to NOAA that our activities were prominent in the President's message to the Congress on Research and Development.

Another measure of the importance attached to our activities by the President is the total increase he has given to NOAA in his budget. The President's request for a 20 percent increase for NOAA is considerably above the average of the increases requested for Federal agency activities.

We are being called upon to mount new programs and expand many of our existing ones. As part of the President's Technological Opportunities Program, we will be heavily involved in major new efforts in the fields of weather modification, earthquake hazards, severe weather observation and tracking by satellites, and mapping and charting our continental shelves to provide a basis for development and management of the oceans' resources. Major new thrusts in the fisheries area will include expansion of our marine resources monitoring, assessment and prediction programs, our State/Federal cooperative programs, and others in the marketing and technical assistance areas. We will engage in a number of major field programs such as the International Field Year for the Great Lakes commencing this spring on Lake Ontario, the new marine ecosystems analysis program involving field work this year in the New York Bight area, and studies leading to similar programs in other parts of the nation. The Atlantic Tropical Experiment of the Global Atmospheric Research Program will be fully supported, and we will move ahead with new technology programs. These include the data buoy project, the Manned Undersea Science and Technology program, the satellite program in which the President has authorized a system of two geosynchronous satellites, and the provision of new fifth-generation computers for fundamental geophysical fluid dynamics research vital to understanding of the ocean-atmosphere system.

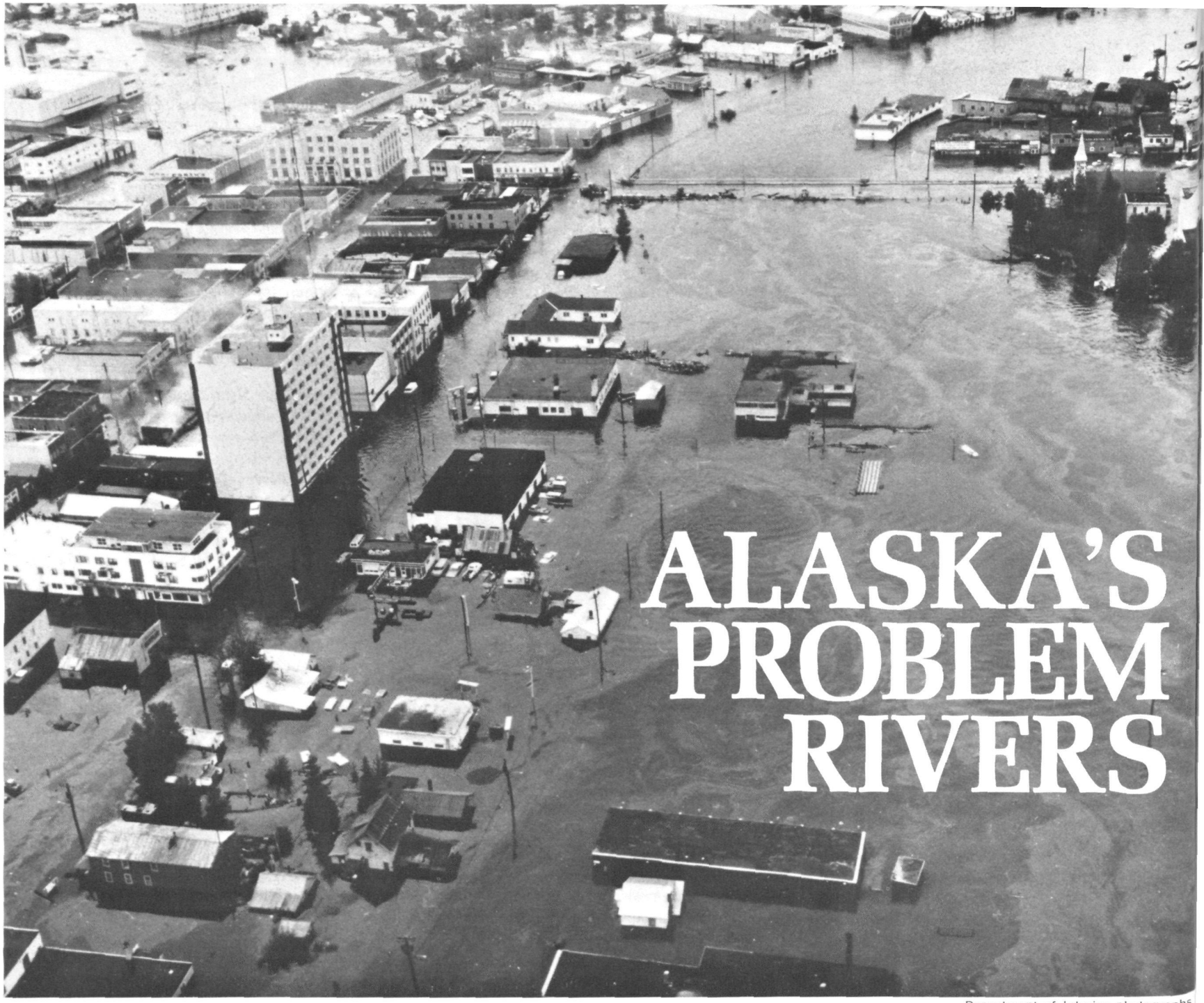
Nor will this program overlook the basic service missions which have been so desperately in need of additional support over the years. Agricultural weather services will be extended to additional states, aviation weather services to new locations, flash-flood warning services to new areas. Our ocean and marine weather forecasting services will be expanded. The President's budget also provides funds for automation of our nautical charting, for the full-season operation of our ship fleet, and for operation, maintenance, and replacement of the equipment and facilities so essential to the continued functioning of the organization.

Our Environmental Data Service will further develop its ENDEX and OASIS systems, designed to provide central services for rapid automated data and literature referral; and will upgrade its National Oceanographic Data Center.

This year, we hope to extend and expand our support for work by groups and organizations outside the Federal government to carry out our NOAA missions. This effort will be led by the Sea Grant program which will enlarge its efforts to build a vigorous marine infrastructure within our university and industrial community which stimulates the transfer of technological capabilities and the creation of new knowledge and new industries necessary for the revitalizing of many of our marine activities. The concept of cooperative work with non-government agencies will be expanded to all of our line components. We hope to break new ground in our activities for mapping and charting the seas, by providing support for industrial companies to assist us in the geophysical mapping of the continental shelves, increase support to our universities in the context of the programs of environmental research laboratories and our satellite program, as well as our fisheries programs.

It is my hope that during this coming year we will take strong action to stimulate and support these national activities. It will be a year of vigorous activity and, I am confident, achievement.

Robert M. White



ALASKA'S PROBLEM RIVERS

Department of Interior photographs

The 1967 Fairbanks flood forced half the people of the city from their homes and property damage was estimated at more than 100 million dollars.

TO CHEECHAKOS (tenderfeet) of the lower 48 states, the very idea of a serious flood hazard in frosty Alaska may seem incongruous. The more-usual image is of a landscape of sculptured ice and snow, perhaps with an Eskimo and his sled dogs loping across a treeless horizon.

The truth is that Alaska has a very definite flood problem—one that is bound to become more urgent as the state's resources—particularly oil from the Arctic slope—are developed, and as its population, which grew by one third from 1960 to 1970, continues to swell.

Ironically, it was an unusual flood caused by summer rains—the like of which occurs in Alaska perhaps once in 200 years—that brought the situation to a head, rather than the chronic flooding from snowmelt and ice jamming that occurs on its rivers. This flood was the disastrous episode of August 1967, during which the Chena River, a tributary of the Tanana and ultimately of the mighty Yukon, overflowed its banks and inundated Fairbanks (population 30,000), causing property damage estimated at more than 100 million dollars.

It began with a freak downpour that was triggered when moist air, channeled northward from the Gulf of Alaska, passed neatly between two mountain ranges. Torrents of rain sloshed down on the horseshoe-shaped basin of the Chena River above Fairbanks. The run-off loosened hillsides, washed out roads, toppled trees from banks, and covered the flood plain of Fairbanks with muddy water up to a man's chin.

Fortunately the rise inside the city was not swift and rampaging, but smooth and steady. Even so, about half the people of Fairbanks were forced to flee their homes as the waters rose through the night. Most of the damage was not caused by the force of the flow, but by structures caving in after basements were pumped out while deep water still surrounded them.

This disaster prompted NOAA's National Weather Service (then Weather Bureau)—along with the Army Corps of Engineers and the U.S. Geological Survey—to begin a joint plan for river forecasting in the Tanana Val-

Ice jams, permafrost and glaciers are factors in forecasting floods in our northernmost state.

BY EDWIN P. WEIGEL

ley. By summer of 1968, a network of six automatic water-level recorders and associated radio and electronic equipment were in place at strategic spots. The system was given a good workout in the summer of 1969 when a similar but lesser rainstorm swept through the valley.

Then, in the early months of 1971, Alaska was provided for the first time with a full-fledged River Forecast Center. The new center was housed with the Weather Service's Alaska Region Headquarters at Anchorage. The Fairbanks Weather Service Office was designated a River District Office. Appointed to man the former were four professional hydrologists, and the latter a hydrologic-services specialist—all under the supervision of Regional Hydrologist Glenn L. Audsley. Thus staffed, the new team began a plan for a full-scale Alaska hydrologic service. A basic framework is expected by mid-1972.

All this is none too soon. An economic boom in Alaska is as inevitable as the annual freeze and thaw of its rivers. A sophisticated river-forecasting service is a natural corollary.

Alaskans are hoping that, because they are new at the river-forecasting business, a way can be found to establish a modern, computerized system from the start, rather than passing through the stage of old-fashioned, manual methods of measuring and forecasting the flow of water, and then switching over to machine.

A quick sketch of the scope of the problem shows why. Alaska boasts a number of major rivers. One of these, the famed Yukon of Gold Rush days, ranks third in the U.S. It meanders 1,875 miles, compared with 3,741 miles for the Mississippi-Missouri-Red Rock System, and 1,885 for the Rio Grande. Next in Alaska is the Kuskokwim, coursing 800 miles before spilling into the Bering Sea. Four great tributaries—the Porcupine, Koyukuk, Tanana, and Innoko—swell the flow of the Yukon, each of them snaking about 500 miles before making juncture. The Colville River—428 miles—dumps icy waters into the Beaufort Sea. Also ranking as major international rivers are the Stikine, the Alsek, and the Taku. And then there are the lakes and glaciers. Lake Iliamna encompasses 1,000 square miles; seven others spread over 100 to 158 square miles apiece. All told, there are three million lakes more than 20 acres in size, and 17,000 square miles of glaciers.

Alaska has 40 percent of the total fresh-water runoff in the United States.

Only because the state has been so sparsely populated has its hydrologic problem been ignored thus far.

The special nature of that problem?

Winter, of course, plays a leading role. The rivers begin to freeze in October. Soon the heaviest equipment can move over them. At ice break-up time, in late April or early May, spring flooding is usually wild.

Equipment in water does not survive ice jams, so there is no automatic network to tell hydrologists about the extent of ice jamming or the size of the cakes. These must be observed first hand on the ground or from the air.

On the ground the problem is being attacked by a system of slope-profile gages along the Yukon River. These are just three rods driven, with heads almost flush, into the bank—one near low water, one at half bank, and one near the top of the bank. This crude measuring system is centuries old, but it has the desirable characteristic of being almost impervious to changing ice conditions. Observers, many of them natives recruited at station sites, report their observations by radio, if a telephone is not available.

The procedure is simple. The observer measures the distance down the bank from the rod that is nearest the water with a tape, and that is his stage reading. During low water, a three-foot section of staff gage wired to a steel post may be read instead of taping down the bank. All slope measurements and staff-gage readings are equated to a standard datum, so that meaningful flood stages can be determined for each community.

This information, flashed to Weather Service hydrologists in Anchorage, forms the backbone of the present flood-forecasting network in Alaska.

Alaska has some peculiarities which give added dimensions to the problems ahead for river and flood forecasting. One of these is permafrost—a layer of soil beneath the surface that has been premanently frozen for perhaps thousands of years because the summers are too cool and short to melt it. Permafrost covers most of the northern third of the state. "It hinders penetration of water into the earth," says staff hydrologist Jerry Nibler. "We suspect it hastens runoff, but we don't really know for sure, or how much. One of our tasks will be to find out by making sample studies."

Another peculiarity is the so-called "self-dumping" lake or glacier-dam lake. This is caused by the damming effect of a glacier

continued

Overseers of Alaska's rivers. From left, Stuart G. Bigler, Director, National Weather Service Alaska Region; Glenn L. Audsley, Regional Hydrologist; Thomas J. Bowers, Hydrologist in Charge, Alaska River Forecast Center; David W. Street and Gerald J. Nibler, staff hydrologists; and Marie Drew, secretary. Not shown are Julius H. Moore, Assistant Regional Hydrologist, and David A. Macfarlane, hydrologic specialist in charge, Fairbanks River District Office.

Observers, many of them natives, report river observations by telephone and radio. Blunka Ishnook (above) is a river observer in New Koliganek Park.

Alaska has 40 percent of the total fresh water runoff in the United States. There are three million lakes more than 20 acres in size, 17,000 square miles of glaciers, and a number of major rivers. (Right) Margerie Glacier in the Fairweather Range. (Below) The Sanctuary River.

on water moving down a tributary valley. The side of the glacier is almost as effective as concrete in holding back the water—until, after a year or two, the lake spills over the top of, down the side of, or underneath, the glacier to form a rapidly widening sluiceway through which the lake "self dumps" in a matter of five to six days. When this happens, 50,000 to 100,000 acre feet of extremely cold water can quickly engulf settlements on the banks. Flood water, trapped inside houses, may even freeze. Several residents of the Kenai Peninsula, facing a houseful of ice, have had to abandon their homes for part of the winter.

Forecasting the self-dumping of a glacier-dam lake is next to impossible, because it has relatively little to do with rainfall or river flows. Alaskan hydrologists are learning how to "babysit" these reservoirs and warn nearby residents when a sudden shift begins.

"Right now," says Nibler, "we are watching three. Two—Skilak Glacier Dam Lake and Snow Lake—are on the Kenai Peninsula. These could inundate some houses along the rivers when they let go. The third is the Tazlina Glacier Dam Lake. We're watching that one because the proposed pipeline from the North Slope to Valdez would cross the Tazlina River and we want to anticipate what might happen."

What is self-dumping like?

"It isn't spectacular to begin with. The water augers a channel somewhere, and the flow of water begins to grow—slowly at first, then faster and faster, discharging at an accelerating pace. Finally, it's coming through at a furious rate. Then it drops off rapidly. On a flow chart, it's a saw-toothed line.

"Water from the two on the Kenai Peninsula drains from underneath the tongue of glacial ice. At the terminus, it boils out so fast it leaves a large, dome-shaped standing wave. It looks like water rushing out of the powerhouse at a manmade dam—only wilder, because there's a lot of debris mixed in—chunks of ice and mud.

"Downstream, the relatively small channel receiving this outflow becomes brimfull of turbulent water choked with sediment. It races around bends, erodes banks, topples trees, and eventually spreads far out over the flood plain."

A similar but rarer type of dumping of a lake took place in August of 1971 when a heavy rain caused a natural dam that had been formed by an ancient landslide to give way. This resulted in the sudden draining of a mountain lake three fourths of a mile long and half a mile wide, augmenting a flood that did six million dollars' worth of damage in the Matanuska Valley, Alaska's prime agricultural area.

No one was on the scene at the time. Just what happened was not discovered until a charter pilot who regularly flew hunters to the lake made a trip up and found the water all gone—just a dry lake bed.

When Weather Service hydrologists made a follow-up trip to the site, they discovered that the lake, 25 miles north of Palmer, had reached a depth of 85 feet, 13 feet above normal, when it broke through the dam by gouging a sluiceway 100 feet deep by 150 feet wide and a half mile long. The outskirts of Palmer experienced considerable flooding; several autos were lost, roads washed out, houses inundated.

"This is probably a relatively rare phenomenon," says Nibler. "It could happen, though, in any mountainous area. It wouldn't be uniquely Alaskan."

These events, along with the sudden releases of ice jams on the major rivers, constitute Alaska's flash-flood problems.

"For routine flood forecasting, Fairbanks is our area of major concern," explains Nibler, "because it is the largest city in a flood-vulnerable area.

"As we get our data organized and get some numerical models that will work, we will forecast for other locations along the Yukon, the Kuskokwim, and the Tanana Rivers." He adds:

"There is quite a bit of barge traffic on all of these rivers. In the summertime, supplies from the Lower 48 come up by barge as far as Nenana, a little town on the Tanana River near Fairbanks, to which goods finish the journey by rail. Barges are like those on the Mississippi—large, shallow-draft, pushed or pulled by diesel tugs. They haul almost everything—building materials, foodstuffs, you name it. Barge carriers have already asked us for help in forecasting low flows on the rivers, so they will know how late in the season they can go upriver and back down again before the freeze. The rivers start to fall as winter approaches, because the snow stops melting. If the barges are upriver then, they're likely to get stuck. It takes three to four weeks to make a round trip."

Freeze-up generally starts around the first of October, and by mid-November the rivers are iced over solidly. Not until the first of April does warming begin. The ice starts to move out about the latter part of April.

Each year there's a gigantic lottery to see who can guess the exact minute, hour, and day that the ice will break up at Nenana. It's called the Nenana Ice Pool. A large, 20-foot tripod is set up on the ice in the middle of the river, and wired to a clock in a little house on shore. When the ice breaks up, it pulls the wire and trips an electrical switch that stops the clock.

continued

In August 1971, a natural dam formed by an ancient landslide gave way, flooding the Matanuska Valley. (Top) The landslide dam and the drained lake. (Bottom) The breach in the dam.

The pot usually holds more than $100,000, but frequently more than one person bets on the same minute with his $1 ticket, so that several share the kitty. Even so, they may net $20,000 to $50,000 apiece.

Excitement runs high, and the river cooperates with a lot of booming, grinding noises as snowmelt waters cause the ice to lift. Sometimes it displays a mysterious process called "candling," when large splinters are squeezed high into the air, almost like fireworks.

Then as the rising water lifts the ice higher and higher, it buckles with loud crunchings and crashings and begins to flow downstream. When it hits a sharp turn in the channel or a constriction, it will jam and dam the water, creating large pools. If a town or village is nearby it will be flooded, which happens frequently.

Says hydrologist Nibler: "The maximum levels are reached during the break up of the ice; the greatest threats to life and property are the floods caused by ice jams, and the hardest to predict. They are one of our biggest jobs.

"Last spring we had severe ice-jam flooding but not one life was lost. We did a lot of aerial reconnaissance to try to spot the ice jams, along with the Corps of Engineers. Usually jams occur some distance from populated areas, so people wouldn't know about them. Whole villages could get caught by surprise when the jams let go, if we didn't provide warnings."

Although ice-jam flooding probably always will call for on-the-spot vigilance, the new team of Alaskan hydrologists is eager to make the most of numerical-prediction methods for covering the flood potential in so large a state, with a minimum of expensive and time-consuming labor.

Accordingly, a multi-agency experiment is now under way to determine in meticulous detail the hydrological and other characteristics of the 40-square-mile Caribou-Poker Creek watershed, located about 30 miles north of Fairbanks, because it "is representative of a large area of interior sub-Arctic Alaska," where the severest flood problems may occur.

In tree-covered elevations from 700 to 2,500 feet, NOAA, the Corps of Engineers, the U.S. Army Cold Regions Research and Engineering Laboratory, Soil Conservation Service and the U.S. Geological Survey, all are cooperating in an effort to measure and study every conceivably significant aspect of this little patch of land. Besides conventional hydrology, included will be microbiology, soil-moisture relations, nutrient cycling, and biological productivity.

Says Jerry Nibler: "Starting out in such a big state as Alaska, it is necessary to do a lot of simulating in areas of little data. We'll begin in the Fairbanks area, developing our numerical procedures. Once we get something we're sure works there, we'll extend it elsewhere, to where the topography and climate are similar.

"Hopefully, we'll be able to move rapidly to a modern system for the vulnerable parts of the state." □

ALASKA
Big, Wild and Beautiful

Alaska is not only the northernmost state. It is also the coldest, the biggest, the least populous, and possibly the richest. (Above) Katmai National Monument. (Below) Dall ram.

Alaska, our 49th state, is a land of superlatives. Not only is it our northernmost and coldest state, it is also the biggest (twice the size of Texas), least populous (with one third as many people as Rhode Island), and possibly the richest, with a 1968 oil strike on the North Slope that may be one of the greatest in history and brought more than 900 millions in bids for oil-land leases.

Alaska has the highest mountain in North America—Mount McKinley, soaring 20,320 feet above sea level, and 17 of the 18 highest peaks in the nation (the 18th being Mount Whitney, in California—14,494 feet). It has the longest tidal shoreline, which, at 34,000 sinuous, craggy miles, approaches that of the entire lower 48 states, measuring 54,000 miles.

The nation's lowest temperature on record was observed January 23, 1971, at Prospect Creek, Alaska, in the southern foothills of the Brooks Mountains—a numbing 80 degrees below zero. The lowest annual average temperature in the U.S. is at Point Barrow, Alaska—9.6 degrees above zero—where you'll also find the coolest summers, averaging 36.7 degrees. Coldest winters are at Barter Island on the Arctic Coast of northeast Alaska, averaging minus 15.6 degrees. Yet, with all these frigid records, a sweltering 100 degrees was recorded at Fort Yukon in July 1915.

Alaska also is a place of great extremes in precipitation, varying by region from an annual average of 4 inches to 220. The Arctic portion, north of the Brooks Range, is as dry as Arizona. Yet the southeastern part, which is shielded by the mountains and draws warmth and moisture from the Alaska current, gets four times as much precipitation as New York City or Washington, D.C. In the central Gulf of Alaska area, much of the precipitation falls as snow. A record snowfall of 975.5 inches (81 feet) occurred at Thompson Pass on the highway out of Valdez in 1952-53, with that same station regis-

continued

Among the state's wildlife is the Alaskan brown bear, a species of grizzly.

The airplane has replaced the husky as a means of transportation in Alaska.

(Left) The Yentna and Lacuna glaciers, Mounts Foraker and McKinley. (Below) Kukak Bay, Katmai National Monument.

tering a record fall in one month of 298 inches (25 feet), in February 1953. A record of 62 inches (5 feet) was measured on a single day in December 1955.

Yet most Alaskans scoff at the "igloo image" lower 48ers have of them. Reason is that most live in modern comfort in the relatively "balmy" portion where Anchorage is situated, which has a climate somewhat like the north coast of Maine. Almost half the total population of 300,000 people lives in and around Anchorage. So, when you note that the state's average density is one half person per square mile, compared with 60 in the lower 48, it's obvious that in areas outside of Anchorage and Fairbanks (the only two cities with more than 25,000 people), urban congestion isn't much of a problem.

In fact, Alaska has at one time been likened to a huge government game preserve, where 53,000 Indians, Aleuts, and Eskimos can still hunt and fish in the manner of the ancestors. (Alaska has more Eskimos than any other place in the world.) When Alaska was admitted to the Union on January 3, 1959, the Federal government owned 99.8 percent of the land, and still owns 96 percent. In this huge happy hunting ground are 100 million acres of timber, principally hemlock and spruce, seven million acres of lakes, and several thousand miles of navigable rivers. It has the nation's only active volcanoes—about 40, all told—and is sprinkled with some 5,000 glaciers and icefields. Also, it is subject to frequent earthquakes. The greatest earthquake ever recorded in North America occurred on Good Friday, March 27, 1964, in Alaska. It killed 114 persons, caused 50,000 square miles of land to heave and tremble, and did about 311 million dollars' property damage.

Alaska's wildlife is just as impressive as its climate and topography. Included are Alaskan brown bears (a king-sized subspecies of the grizzly), polar bears, black bears, timber wolves, wolverines, lynx, foxes, snowshoe rabbits, moose, caribou, mountain goats, Dall sheep, musk oxen, bald eagles, ptarmigan, spruce grouse, puffins, walrus, sea lions, seals, sea otters, salmon, trout, tom cod, smelt, king crabs, scallops, and shrimp —to name only a few of the more illustrious. Many of these are delicious. Some of them, such as the brown bears and polar bears, feel the same way about people.

Alaska, like Ireland, has no snakes.

In all this vast territory, covering 586,500 square miles, or 375 million acres, and stretching 2,000 miles east to west and 1,100 miles north to south—there are only a few million acres suitable for crops. Less than 100,000 acres is actually under cultivation, much of this in hay, silage, and pasture. Milk and vegetable crops are also important, which introduces more superlatives. The growing season is short, averaging about 160 days a year, but 16 to 19 hours of sunshine a day produces some of the finest and/or biggest vegetables grown anywhere, such as 60-pound cabbages and 30-pound turnips.

In keeping with the rest of its wild and youthful character, Alaska is short on surface transportation and long on aircraft. There is only one railroad, the government-owned Alaska Railroad, which runs north 470 miles from Seward to Fairbanks, and about 3,000 miles of surfaced roads. Yet the state has a dozen local airlines and about 700 airfields. One of every 54 residents has a pilot's license. International air carriers use it as a major way-stop for crossing the Pole.

Now that serious efforts are under way to find a means of transporting vast quantities of oil from the North Slope to consumers in the lower 48, Alaska's prospects for development are greater than ever. Officials undoubtedly will be calling for a host of sophisticated new services from many disciplines, a large number of which will no doubt come from members of the NOAA family. □

Gerald J. (Jerry) Nibler, age 31 (born September 5, 1940), provided much of the background for this article in a 90-minute interview at Weather Service headquarters in Silver Spring, when he was there to participate in a Forecaster's Training Course in December.

Jerry has been a staff hydrologist with the new River Forecast Center in Anchorage for almost two years. He seems tailor-made for the rugged life of flood forecasting in our coldest and wildest state.

A native of Oregon, Jerry loves to ski, fish, and hike. He has a flight-instructor's license and has been flying airplanes since the early 1960's when he was a college student, and he spent his own hard-earned money to become a pilot. During his service career as a meteorologist, Jerry earned extra cash, off and on, teaching others to fly.

His educational and military career includes four years at Portland State College, where he earned a bachelor's degree in applied science in 1963; officer's training at Lackland Air Force Base, Texas, where he was commissioned a 2nd Lieutenant in March 1964; meteorology school at St. Louis (Mo.) University, where he was graduated in June 1965, as a meteorologist; two years at a weather detachment at Davis-Monthan Air Force Base in Tucson, Ariz., during which time he was deployed to Vietnam for five months and provided meteorological support for a classified reconnaissance unit; one year as detachment commander of a weather station in support of an Army unit at Fort

Living and Working In Alaska

Carson in Colorado Springs (where he left the service in August 1968), and two years of civilian graduate work in hydrology at the University of Arizona at Tucson.

In 1970, Jerry joined the Weather Service, reporting for duty at the River Forecast Center in Anchorage in June, along with his wife Kathleen and their daughter Caroline.

Now that he's had a solid sample of what Alaska has to offer, Jerry says he's "glad 90 percent of the time" that he's there; 10 percent of the time he might like to be someplace else.

Mostly, he enjoys "the opportunity to participate in the development of a new state." He adds: "I especially like the informal and friendly atmosphere of Alaskan society."

Along with the good, though, there is a little bit of bad, as Jerry admits. "The hardest thing to get used to was the high prices for just about everything." His duplex home (two bedrooms on the main floor and a bedroom in the basement, plus a heated, two-car garage which he shares with a tenant) is quite expensive," but "labor is the really costly thing.

"Skilled labor is especially expensive. Glenn Audsley, Regional Hydrologist, had a repairman come out to work on his refrigerator and was charged $17 for the first 30 minutes and $7 for each quarter hour thereafter —$31 an hour!"

If Jerry's TV breaks down, he'll throw it away and buy a new one.

Also expensive is any kind of perishable food—vegetables, fruit, meat, and so forth. "A tomato for a salad cost me 70 cents—and it was tasteless." But Jerry saves money, as many other Alaskans do, by filling his freezer with fish and game, especially moose, that he brings home from outings.

"Almost any other kind of game my wife won't eat," he says. "But she really likes moose—a little drier, darker, and browner than beef, but more nutritious because it has less fat, thus less cholesterol."

Jerry says, somewhat pensively, that the 25 percent cost-of-living allowance for Federal workers in Alaska, "probably just about covers the additional cost in housing," at least for the Anchorage area, where he lives, although he doubts it does in more-remote sections.

"Another definite disadvantage is those long, cold, dark winters in Anchorage, during the mid-part of which the sun comes up only four hours. You go to work in the dark, do most of your working and shopping in the dark, and come home in the dark. It can get to you. Cabin fever is no joke, particularly for people new in Alaska. You have to find ways to keep yourself from feeling penned up. It's true that people who ordinarily get along great will start irritating each other unless they develop new interests. Even the old-timers say this. You learn to socialize, even if it doesn't come naturally.

"But when it is light for those short periods, the scenery is gorgeous. It's so beautiful, my wife and I like to go outdoors just to admire it. Primarily we like cross-country skiing. Kathleen and my daughter are taking up ice skating. Other people take up inside activities—handicraft, polishing rocks, painting.

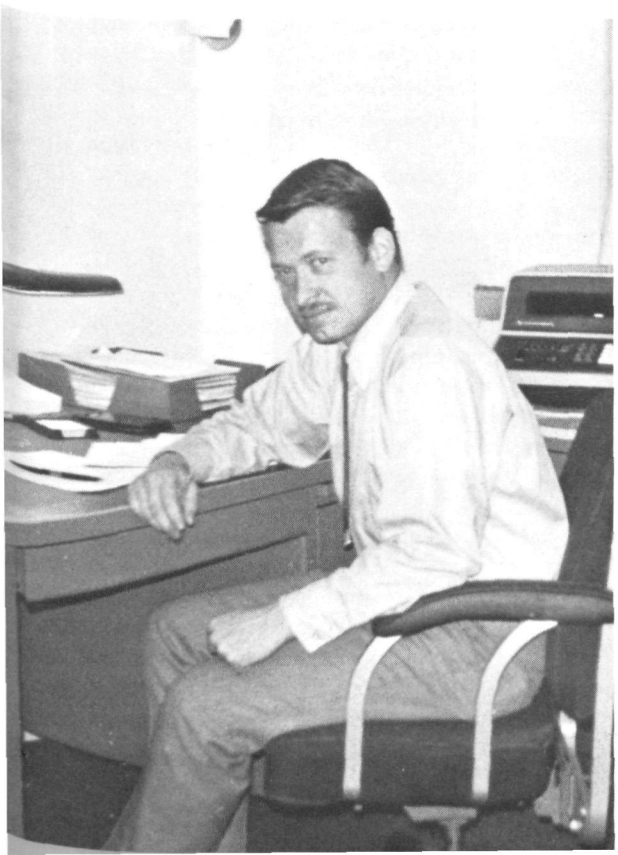
"We like the outdoors, and we really make up for those dreary winter months in the summer, when the sun is visible 15 to 20 hours a day. We do a lot of fishing, hiking, and camping. Every weekend we take off and go someplace new—woods, mountains, lakes. We like to pick blueberries and cranberries toward the end of the summer. Then we see a few bears—so far only black bears. Grizzlies are the ones you have to worry about. Just last summer two people were mauled about 40 miles from Anchorage. The brown bears (of which the grizzly is one) are very temperamental. Most people carry some sort of a sidearm when in bear country. Whatever you carry, it has to be large.

"The fishing isn't as good as I had thought it would be close to the cities, but if you take a plane into the hard-to-get-to places, it's terrific. A fellow and I flew into a little place on the Kenai Peninsula and caught so many humpys (hump-backed salmon), we had to stop. We didn't want to overload the airplane."

And his wife's reaction to Alaska? "Kathleen didn't like it too well at first but she's getting to enjoy it pretty well now.

"We just might make it our permanent home." □

"We like the outdoors," says Jerry Nibler (below), "and we really make up for those dreary winter months in the summer. We do a lot of camping, fishing, and hiking. If you take a plane into the hard-to-get-to places, the fishing is terrific."



What does the future hold for Narragansett Bay? Rhode Island Sea Granters combine ecology and economics to predict the probable effects of man's activities.

CRYSTAL BALL FOR THE BAY

BY JAMES J. NAPOLI

Activities oriented toward Narragansett Bay are worth about 470 million dollars a year in personal income for Rhode Islanders. It has commercial ports, oil terminals, ship and boat building facilities, marinas and other recreational industries, fishing ports and, most important, the Navy.

Narragansett Bay is the natural habitat for about 22,000 registered motor boats and motor yachts and several thousand sailing craft that course through its water for up to eight months a year. It is beaches in the summer.

Narragansett Bay absorbs and transports sewage from the state.

Whatever their perspective, for Rhode Islanders, Narragansett Bay is *mare nostrum*, the body of water whose presence suffuses the entire state and its history.

If you define the bay as all the salt water touching on Rhode Island's 419 miles of rumpled coastline, then about 64 percent of the state's population lives along the bay in 17 coastal communities. About 9,000 civilian employees of the Navy, another 1,000 fishermen, about 500 in marine-oriented recreation industries, and others are engaged in work directly related to the bay. Many thousands use the bay for pleasure.

The uses are pressing on one another. And the task of predicting their consequences—to each other, and to the bay as a whole—is becoming critical. The NOAA-sponsored Sea Grant Program at the University of Rhode Island has undertaken this task.

Dr. Lewis M. Alexander, chairman of the geography department at URI, once identified three stages common to the development of coastlines. The first is "parallel development," when the various resources of the area can be used in different ways without interfering with each other; the second is "competitive development," when the various uses of the area begin to conflict; and finally, "controlled development," when the government takes an authoritative role in deciding how the coastline will be used.

With the creation of the state's Coastal Resources Management Council last year, Rhode Island made the transition from the second to the third stage. The 17-member council is responsible for planning the uses and managing the resources of the coastal region.

James J. Napoli is a marine affairs writer for the University of Rhode Island.

URI, with its recently formed Coastal Resources Center—in effect, the state's coastal zone laboratory—will bear some of the burden. An integral part of this effort is the university's Sea Grant program, whose success was marked last August when the Secretary of Commerce designated URI as one of the nation's first Sea Grant Colleges.

The bay—focus of these planning, research, and management efforts—is in transition. Only about 11 percent of the state's coastline is still available for development and many changes have taken place without regard to their effects on the ecology of the area. Municipal and industrial sewage and waste disposal operations are carried on, channels are dredged, marshlands filled, and residential and industrial complexes sited there.

More activities have been proposed that could also seriously affect the bay. There are proposals for a power plant, possibly nuclear, for North Kingstown; liquid natural gas facilities in Portsmouth and on Conanicut Island; a Navy landfill operation at Coddington Cove; and a regional sewage plant at Narragansett Pier.

Deciding what will be permitted in the coastal zone is not simply a matter of weighing economics against ecology. The problem, in most cases, is that the interrelationships between the two factors are unknown.

The probable ecological effects of a change in the coastal zone—say, the construction of a new fertilizer plant—have never been measured. Similarly, the probable economic effects of an arbitrary decision to reduce the concentration of a specific chemical in the bay—by reducing the amount of industrial effluents containing the chemical—have also not been determined.

The management council would need a crystal ball to foresee all the consequences of any proposed change in the coastal zone or in the bay itself before they occur.

This "crystal ball," complete with computer printout, is being developed by the URI Sea Grant program. In the vogue now past, the crystal ball was called a "model." It is now called a "systems analysis," though the word "model" persists unofficially.

Dr. Niels Rorholm, the tall, urbane coordinator of the URI Sea Grant program, commented that the difference in terminology is something more than semantics.

"To set up a 'model' that takes into account every single economic factor around the bay and its effect on the biota of the bay would be a massive and extremely complex undertaking. If you mean what you are saying, then it is perhaps impossible," he said.

"Our physical and economic models will be integrated with studies in systems ecology. We are not looking toward the creation of a 'super model.' We are merely approaching research in the bay in a systematic manner. This, in turn, will enable us to predict systematically effects upon the bay of manmade changes. An example of an immediate use of a physical model would be in predicting the spread of oil in the bay after a spill. A long-range use of the integrated model would be in predicting the probable effects of growth in Rhode Island industry or population in certain areas.

"Up to now," he added, "there's been a feeling that there have been more models than answers. This is probably a natural thing since the use of models in resource management is a recent development. But we mean to make ours work."

In its broad outline, the objective of the systems analysis is to develop a mathematical way to simulate and integrate the Narragansett Bay "systems." These are the physical system, which includes tidal heights, currents, salinity, temperature, and concentrations of certain chemicals, such as dissolved oxygen; the biological system, including plankton metabolism, bottom respiration, sediment organic content, and fauna in and above the sediment; and the socioeconomic system, including the types of industry and the concentration of population along the coast.

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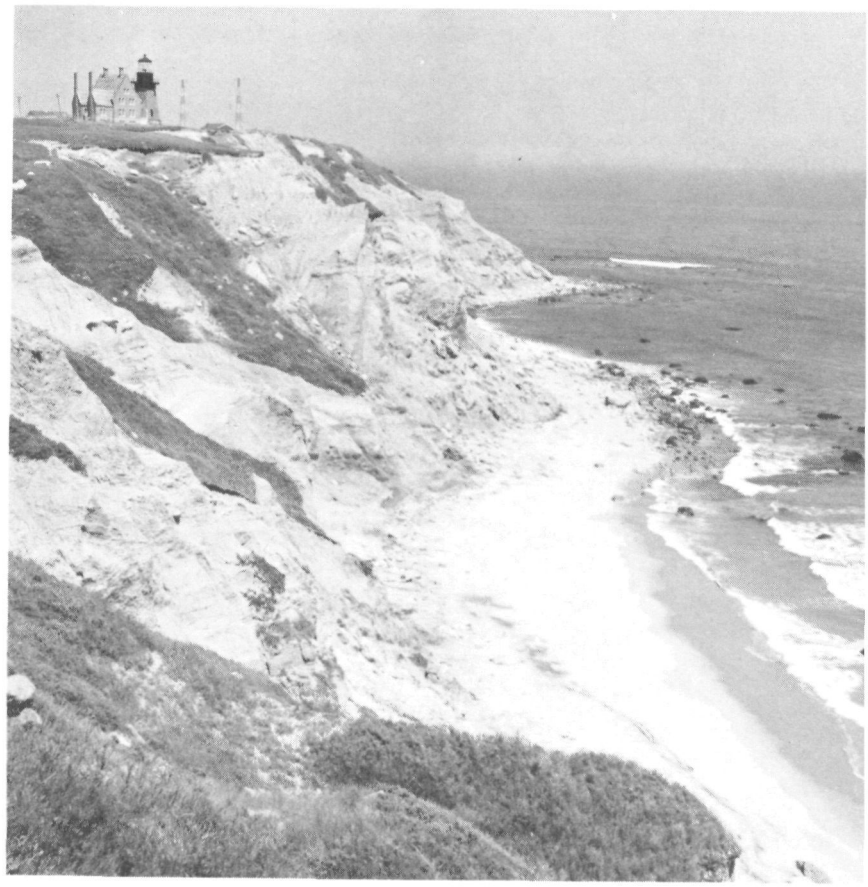
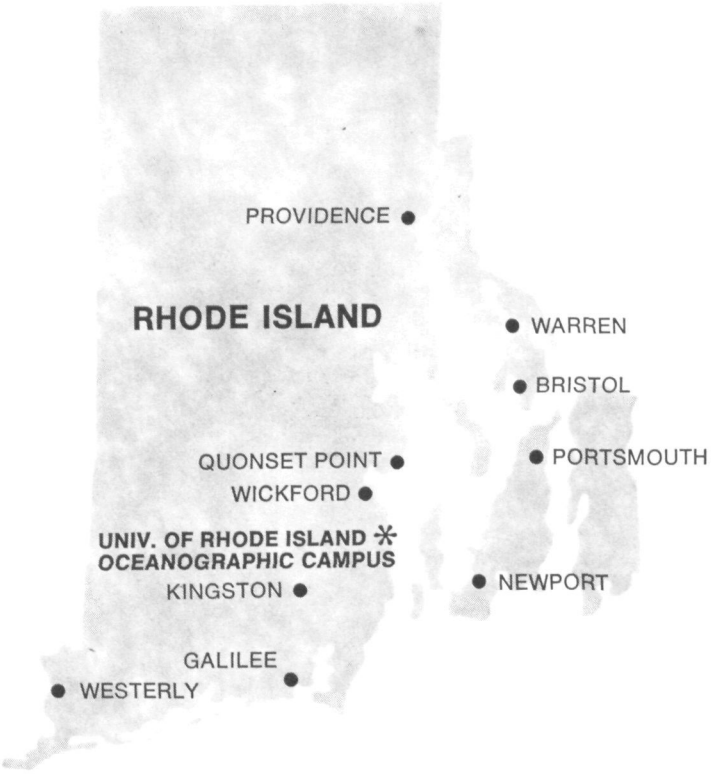
The bay is in transition. Only about 11 percent of the state's coastline is still available for development, and many changes have taken place without regard to their effects on ecology.





The ultimate goal, said Dr. Rorholm, is to provide a master tool that can guide decision-making for the bay. "In the sometimes fast-moving world of political decision-making," he said, "the model should at least be good enough so we can plug in a question and get out an answer close enough to reality to require only a minimum of interpretation."

At this stage, the most obviously successful aspect of the systems analysis has been the physical analysis of the bay under the direction of Dr. Frank M. White, a URI ocean engineer. "That is good because the physical model is the natural starting point," Dr. Rorholm said.

After cutting their teeth on a physical systems analysis of Point Judith Harbor of Refuge, Dr. White and his students bit off the entire bay. They divided the bay into about 316 half-mile squares and took measurements for a series of physical parameters, which were then fed into a computer to develop a predictive model.

According to Dr. White, "we have now gotten to the point where we can determine tidal height and tidal currents in any part of the bay at any time in history, either past or future."

The analysis has been tested for accuracy by actual observations of tidal rise and tidal currents at various points in the bay and also by "predicting" the surge from the hurricanes of 1938, 1944, and 1954.

"Our computer-predicted surges of those storms were in agreement with what actually took place," he said. Dr. White added that if the wind direction, velocity and time of a hurricane are fed into the computer, it can figure out "the worst damage that could possibly happen on the bay as a whole or on any specific point on the bay. We can figure out what the flooding will be around Wickford Harbor or the surge at Narragansett Pier at any point in time."

The ocean engineers have also found ways to compute how long it would take a given particle of water to be flushed out to the open ocean from any given point of entry in the bay—an application particularly useful for pollution studies, Dr. White said.

(Above) Jutting deep into Rhode Island, from Newport to Providence, is Narragansett Bay. (Below) The University of Rhode Island's Narragansett Bay Campus, site of the graduate school of oceanography.

And they have drawn a new tidal chart, considerably more accurate than anything that preceded it, as a result of their analysis. Models of temperature, salinity, and chemical concentrations are still being refined.

"The finished model will be able to take account of any proposed changes in the dynamics of the bay, such as hurricane barriers, thermal discharges, sewage outfalls and channel dredging," according to Dr. White. "When we started our modeling effort, it seemed that everybody in the world also started modeling—Massachusetts Bay, Galveston, the Great Lakes, Chesapeake Bay. But we have shown it can be done—and successfully."

A report of progress on the physical analysis so far is being prepared by one of Dr. White's students, Kurt W. Hess.

Recalling the initial attempt at modeling under Sea Grant in 1970, Dr. White mused: "It took us a long time to get up the nerve to take on a project we knew would be long-term. Then it took a long time to get the model and take the bugs out of it. When the model didn't predict accurately, we had to go back and play with it and tune it. Now we're getting results. It was once enough to say that I'm studying something. Now it's 'look what I've found in milligrams per liter.' "

In the words of Dr. Scott W. Nixon, an ecologist who is chairman of the system analysis team, the "most challenging" part is yet to come. Dr. Nixon is in charge of developing the ecological systems analysis and, together with Harlan C. Lampe, a professor of resource economics, of integrating it with the physical and socio-economic models.

Like Dr. White, Dr. Nixon first employed the systems approach on a smaller scale. He developed a simulation model of the daily dissolved oxygen patterns of a small tidal marsh at Bissel Cove in North Kingstown, a report of which is being prepared.

This model is now being used to explore the probable effects of heated water and sewage inputs on levels of dissolved oxygen. Additional studies on the ecology of intertidal communities in the bay have been devoted to mussel beds and sea grass meadows.

Dr. Nixon and his associate, Dr. Candace A. Oviatt, are now turning the skills they have gained in the systems analysis of the tidal marsh to the bay itself. Included in last summer's work were attempts to measure the plankton photosynthesis and respiration in the surface and bottom water at locations throughout the bay, to survey fauna in and above the sediment, and measure the sediment's organic content and oxygen consumption.

A major factor in regulating the seasonal cycles of plankton in Narragansett Bay are the large pulses of grazing animals that develop within or migrate into the system each summer. For north temperate bays, such as Narragansett Bay, dominant grazing populations include the comb-jelly, mnemiopsis, and schools of menhaden.

"Exploratory studies begun this summer have documented the great abundance of these animals and provided intriguing numbers suggesting their impact on the bay system as consumers of zooplankton and phytoplankton, respectively, as well as through nutrient recycling. For the first time we have been able to get quantitative estimates of mnemiopsis populations and to measure the effect of menhaden schools on plankton and water chemistry," said Dr. Nixon.

According to Dr. White, the ecological model can be married, or interfaced, with the physical model fairly easily. "We will be able to take the change in temperature of a point in the bay and be able to compute the changes in the phytoplankton population. Or, we can determine how increased nutrients from a proposed sewage outfall will affect the concentration of plankton," he said.

To marry the ecological and economic models is somewhat more complex. But the concept is not new.

The state's economy is being boiled down to about 30 sectors, and an attempt is being made to develop a model for the flow of goods and money between these sectors. This economic model, in turn, will be integrated with selected ecological coefficients, such as

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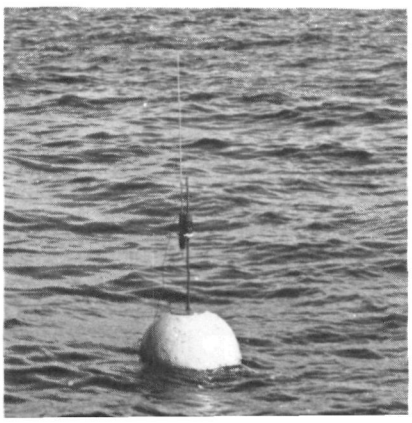


A Bay Watch project, to provide data for the computer models, employs a variety of platforms and instruments. (Left) Sen. Claiborne Pell, Dr. Werner Baum, Mrs. Pell, and Dr. L. LeBlanc at the ceremonial launching of URI's multiple-sensor buoy. (Left, below) An accelerometer buoy measures the size and frequency of waves.

For Rhode Islanders, Narragansett Bay is the body of water whose presence suffuses the entire state and its history. It provides work for many, and pleasure for others. It also transports sewage from the state.

B.O.D. (Biological Oxygen Demand), coliform and chemicals associated with each industry.

"We hope that as we project changes in the economy along the bay, we will then know what it is that will be dumped into the bay, or will stop being dumped into the bay," Professor Lampe said.

"Say there was going to be a new development in South County," he speculated. "We would be able to predict the effect on the distribution of our economy, and, subsequently, the effect on the quality of the bay, or the effect on clams in the bay.

"Depending on where the development was to be built, it would reduce or increase the population on the bay, or it could affect the kinds of industries on the bay, or the number of households—all of which is relevant to what goes into the water."

The model would also work like a two-way street. "We could predict what the influence on the economy would be if we tried to reduce an ecological coefficient, say the coliform count in a section of the bay. We would be able to determine who would be most affected—households or industry—and what the cost would be," Professor Lampe said.

Once in working order, the integrated model would still have to be continually updated, he said. "We will change the model so that its predictions approach more closely what happens in actuality. To the extent that things happen as predicted, we're happy; to the extent they don't, we're unhappy."

Some of the data being fed into the computer for the models, particularly for the physical model, is being obtained by a dozen ocean engineering faculty and staff members working under a project called "Bay Watch." These men, working on the bay, obtain the measurements needed for developing the models. Once the models are developed, these men make sure that they accurately represent what happens in the bay.

Bay Watch is under the direction of Dr. George A. Brown, professor of ocean engineering.

In the past year, the engineers have conducted on-location studies of currents and tidal heights in the bay. They established a data bank for obtaining and distributing information on the bay to private and public organizations; they have taken water quality measurements and surveyed trace metals in the sediments near industrial and government sites; and have conducted a feasibility study for fish population measurements using advanced sonar and data processing systems.

Most of their work was done aboard the research vessel ISLANDER, continually traversing the bay taking the necessary measurements.

To meet the need for monitoring the bay for long periods of time in a single location, the ocean engineers have also fabricated a buoy containing multiple sensors that will relay a constant stream of information to a receiving station at URI's Narragansett Bay Campus.

The buoy was officially launched in January. Among the two dozen people standing on the snow-swept dock at the bay campus for the launching ceremony was Senator Claiborne Pell of Rhode Island, co-sponsor of the bill creating Sea Grant in 1966.

Dr. Brown, sitting in his office, framed by tilting piles of papers and books, commented, "Because of its mission orientation, Sea Grant is looking for an economic payoff.

"Since our model will help in making management decisions about the use of the bay, it is a natural for Sea Grant funding. Coastal management studies are as important to URI as oil or dredging studies are to Texas A&M—because there is a strong economic implication for the state," Dr. Brown continued. "We hope to become one of the leading groups in the country for resource management and prediction."

The systems analysis, including planning and collection of preliminary data, has been under way for three years and is nearing the point of useful application. Dr. White has commented:

"I think that by June 1973, the physical model will already be a useful tool; the biologists will have integrated their model for the lower levels of the food chain; and the gross aspects of the economy will be integrated into the overall model."

Professor Lampe forecast that a viable model will be available for public use "in a couple of years," although a more sophisticated model will take longer.

"It may not be realistic to expect a magnificent model of every interaction in Narragansett Bay," said Dr. Nixon. "But we are getting something going here. The most exciting part, when the different analyses of the bay can be made to interact as an integrated whole, is just ahead." □

DUST DEVIL

BY JACK R. COOLEY

This cyclonic prankster may play an important role in the atmosphere's energy balance.

A small member of the family of atmospheric cyclones earned a place in history nearly 13½ centuries ago, through its reported role in Mohammed's first battle.

Awakening from a spiritual trance at a critical turn of the fighting, Mohammed impulsively picked up a handful of dirt and flung it toward his enemies with a holy curse. He mounted his horse and charged like a madman into the midst of the fray, followed by a very small dust devil that had curiously sprung to life from his cast handful of earth.

As the wrathful prophet dashed forward, it is said that the whirling spiral of dust behind him grew rapidly in size and speed until it drew abreast of Mohammed and swept with full fury into the masses of enemy swordsmen. In a few minutes, the enemy was so blinded and confused by the unexpected storm that most of them turned and fled, thus assuring the first Moslem victory.

Despite its small size, the dust devil is a vigorous atmospheric circulation, created when highly unstable, dry air near the ground becomes superheated by solar radiation, breaks through the boundary layer, and shoots upward. It has an average lifetime of a few minutes and is frequently made visible by debris from the ground whirled aloft by the updraft of rising air.

Its load of dust may be quite large. In Mexico, one dust devil hovered for four hours over a single spot where a railroad embankment was under construction, removing about a cubic yard of sand per hour.

But they do not necessarily contain dust or debris in sufficient quantities to be readily visible. Many form or drift over areas with such a limited supply of loose surface material that they are invisible aloft and detectable only by observations of the surface vegetation or by physical measurement. Yet there can be little doubt that the basic circulation thus encountered is nearly identical to the one which is visible because of surface debris drawn into its circulation.

Typically, a dust devil is shaped roughly like a cone, with the apex near the ground and the base some distance above ground level. It is generally several yards in diameter at the base and may narrow for a short distance upward, then expand again, like two cones apex to apex.

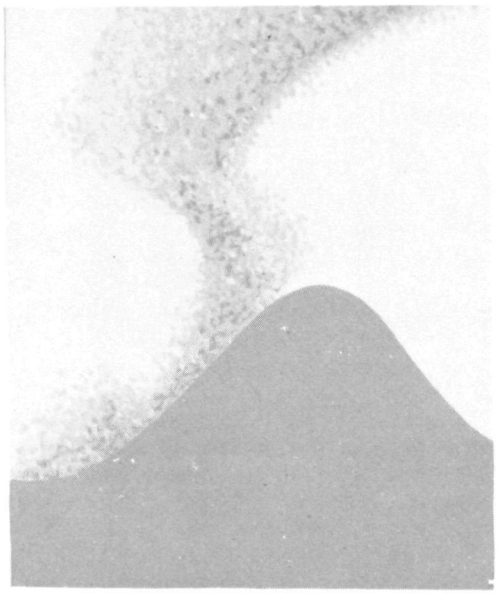
Their height varies over wide ranges, but normally they are only visible up to heights of from one hundred to three hundred feet. Frequently, however, tropical and subtropical dust devils may have a visible height in excess of 5,000 feet. The invisible disturbance has been detected at altitudes of more than 12,000 feet above ground level. The detectable disturbance at that level has a diameter of from one-fourth to one mile.

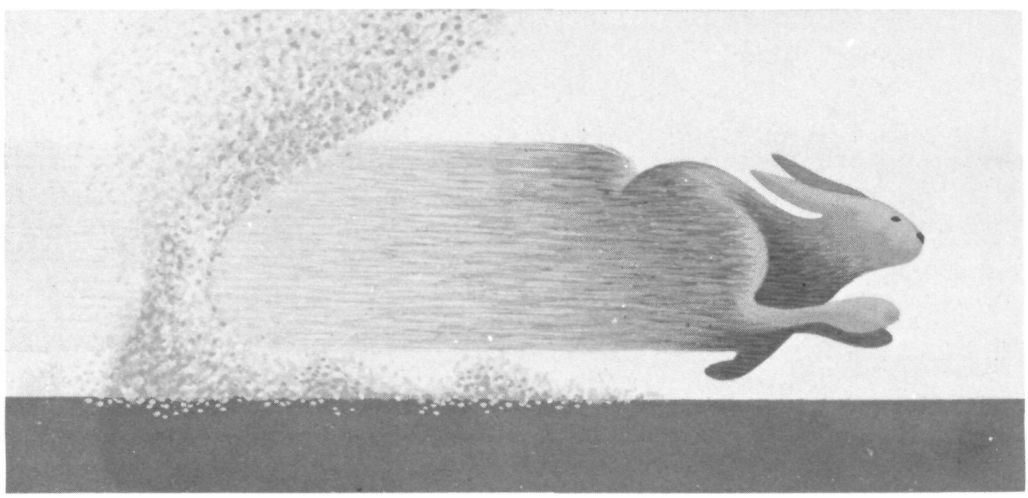
Though smaller and generally less violent than tornadoes, dust devils should by no means be considered harmless. There is a

continued

Jack R. Cooley is a National Weather Service meteorologist, stationed at Grand Rapids, Michigan. The article is based on his May 1971 Technical Memorandum, "Dust Devil Meteorology" (NOAA TM NWS CR-42).

(Below) The dust devil may be triggered by some chance circumstance, such as air set in motion by the activity of small animals. The path of a jackrabbit across the desert may be marked by a succession of small dust devils. (Right) Once a dust devil has formed, it seeks higher terrain. Reaching a small hump, it may remain there for an indefinite period. (Far right) A dust devil interrupts a baseball game.





record of one striking the locomotive of a moving train in western Kansas with such force that the engineer could feel the cab shake, but no material damage was done. On the other hand, they can do considerable damage to grain fields, especially near harvest time. There is no record of dust devils causing structural damage to buildings or loss of life, but they have been known to break windows and hurl loose boards through the air.

These disturbances also are significant agents in the spread of debris and pollen. Their updraft may often be strong enough to carry objects as large as cornstalks or packing cases hundreds of feet aloft. Debris, seeds, leaves, pollen, and dust are raised many thousands of feet into the atmosphere and ejected, resulting in downwind fallout over a large area.

Frequently, the dust devil is more mischievous than damaging. In one reported incident, an army sleeping cot was raised several yards in the air. In the Sahara Desert, they have been strong enough to blow a man out of a tent. Three people caught in a dust devil in Lubeck, Germany, had great difficulty keeping their feet. Their clothes flapped vigorously, and they had to hold onto their hats tightly.

The phenomenon should not be treated lightly by pilots, especially in light aircraft flying at low speeds. A Texas pilot nearly lost his life and airplane when he flew through an almost invisible dust devil over a vegetated area where little or no surface debris was available to form a visible column.

Pilots intending to land on a superheated runway, especially in desert areas, should carefully scan the airport and an area two to three miles upwind for dust swirls or grass spirals, in order to avoid penetrating a dust devil at low altitude and near-stall speeds. They should also be alert to the possibility of formation during landing or takeoff and take evasive action if one forms along or crosses the intended flight path.

Dust devils have been reported at latitudes from the tropics to Canada, Scotland, and Iceland. Those observed in Iceland occurred over vegetation-free plains of black lava sand during the middle of the day and extended as high as 3,000 feet. They are encountered rarely in areas of deciduous forest, well-watered grassland, salt marshes, or over lakes and seldom over areas with pronounced topographical relief such as badlands, dissected plateaus, or mountains. On the other hand, a favorite point of origin is at haycocks, road-

side slopes, piles of stone, or at the edge of a plateau. These objects offer a break in the lower boundary layer, where the superheated air near the ground may begin to rise and finally escape in the form of a dust devil.

If it were possible to make a world study of their frequency, one would undoubtedly find a maximum of occurrence in the barren, arid regions of the tropics and sub-tropics, with activity diminishing to near zero in similar areas of the polar regions. Activity at a particular latitude would range from a maximum over barren, arid regions to a minimum over well-watered, well-vegetated regions and regions with pronounced topographical relief, or with slopes having low solar incidence angles. They occur most often in the summer months, with the greatest activity between 1 and 2 p.m. local sun time, the time when ground level temperature is at its maximum.

Although favorable conditions for dust devil formation persist over deserts for several hours during the middle of summer days, few have been observed to last for even a fraction of that time. Typical observed lifetimes are of the order of seconds or minutes. There have, however, been a number of cases where these "average" lifetimes have been greatly exceeded. In Utah, for example, a dust devil some 2,500 feet high was observed continuously for seven hours along a 35 mile path; another near Cairo, Egypt, lasted for five-and-a-half hours.

It appears that a dust devil can continue to exist, if stationary, until it exhausts the available supply of heated air, or in lateral motion until it travels out of a favorable environment. When stationary, a life cycle of approximately eight hours might be possible, but few have been observed to last more than a couple of hours.

The phenomenon may be triggered by some chance circumstance, perhaps a pile of rock at the edge of a wood, a confluence of extreme heat sources such as a road intersection, or air set in motion by the activity of small animals. In some instances, the path of a jackrabbit or a coyote across the desert is marked by a succession of small dust devils. The Apache Indians are said to have produced dust devils deliberately, by setting fire to the spines of a column-like cactus which is common in the southwestern United States. The creation of eddies by some means or other seems to be a necessary trigger mechanism.

Once a dust devil has formed, it seeks higher terrain. Field observations indicate that its path is largely determined by local topography, provided little or no wind is present. It usually will not descend a slope, even if aided by wind. It will, however, move across a slope with little deviation, unless influenced by local wind.

Reaching a small topographical hump, it may remain there for an extended period, usually removing all loose dust and other light debris from the immediate vicinity. This commonly occurs in flat desert areas over large anthills.

More frequently, dust devils move slowly and erratically in a fairly definite direction, appearing to move from one patch of superheated air to another. The net travel is about the same, with respect to speed and direction, as that of the local wind.

Until recent years, only limited measurements had been taken within dust devils. Many of these were the result of chance, when one passed over an instrumented site. Both the chance measurements and those deliberately made were almost without exception nonrepresentative, because the instruments used were not sufficiently responsive or sensitive to give satisfactory measurements.

In the early 1960's, an extensive study of dust devils was undertaken by P. C. Sinclair for his doctoral studies at the University of Arizona. Dr. Sinclair measured a warm core, low pressure center and a vertical structure extending far above the visible dust column —often to altitudes exceeding 12,000 feet above the ground. The vertical motion experienced above disturbances of this size was found to range from a few hundred feet to 2,000 feet per minute—that is from a few miles per hour to over 20 miles per hour. The size of the updraft region increased with height and was found to have a diameter of as much as a mile at altitudes of around 12,000 feet above ground level.

Dr. Sinclair's measurements indicated that surface air is pulled rapidly into the outer portions of the vortex and spirals upward. In the center of the vortex, air is circulating downward. The vortex of the dust devil has a marked similarity with others in the atmosphere.

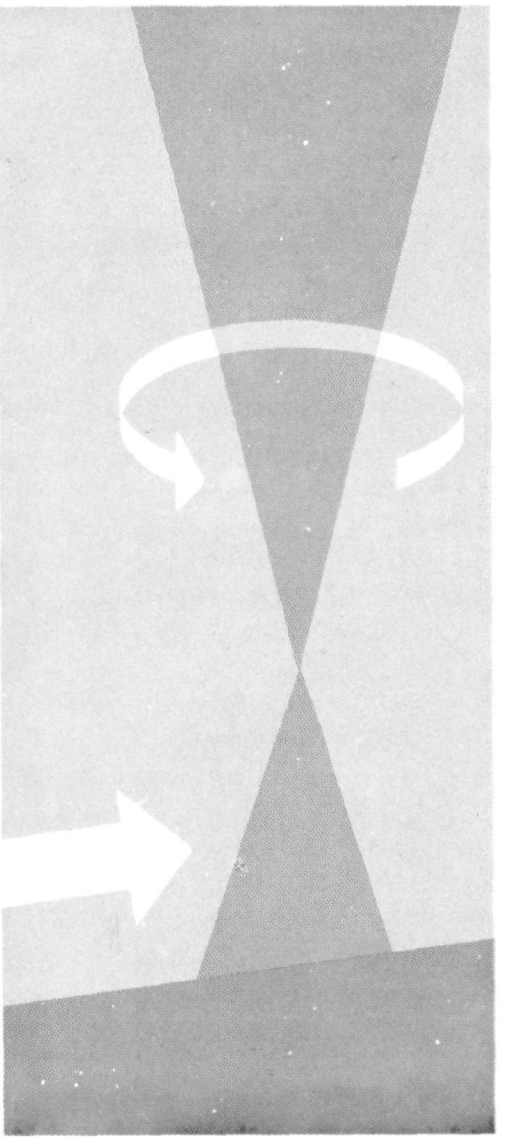
This similarity affords one of many valid reasons for studying the dust devil. It is much easier to find and make measurements in the surrounding environment and within the vortex, than in a tornado, thunderstorm, or hurricane; yet in many respects these circulations are alike. It is not unreasonable to assume that a complete analysis and understanding of the dust devil would provide new insights into the processes involved within—and our ability to predict the behavior of—these other larger, more destructive, and relatively elusive, atmosphere circulations. Moreover the dust devil is a natural atmospheric phenomenon that may play an important role in the energy balance of the atmosphere, particularly in desert regions during summer months. Significant steps have been taken toward making a complete analysis of the dust devil, but much remains to be done.

One nagging question lingers: Is "dust devil" an appropriate or representative name?

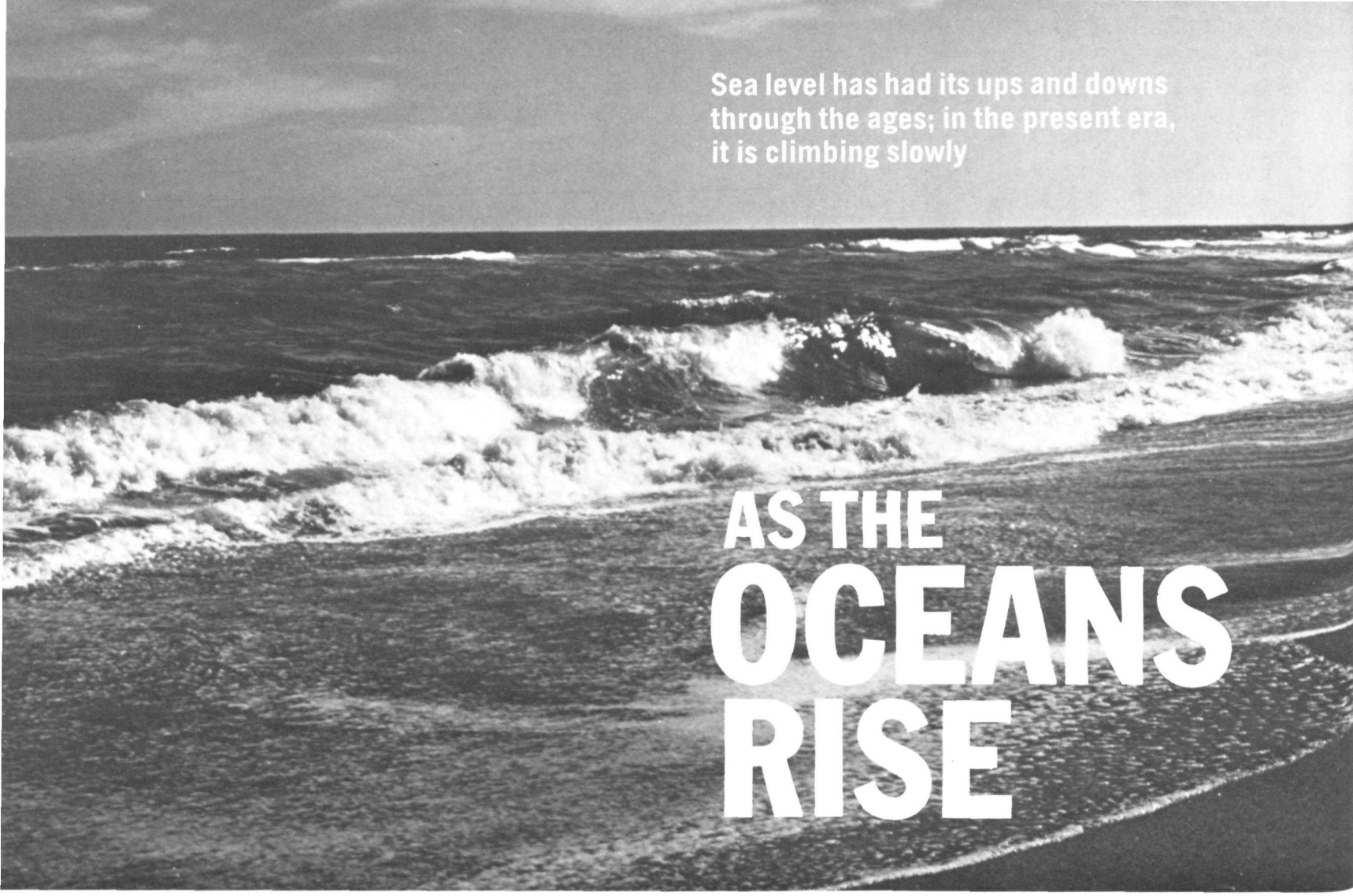
We recognize and differentiate between tropical and extra-tropical cyclones, yet we use the term "dust devil" to denote a phenomenon that may contain little, if any, visible dust. We now know that its circulation and influence extend far beyond the visible dust extremities.

Neither "dust devil" nor "whirlwind" defines the original source of energy; "thermal whirlwind" would not differentiate it from those caused by forest fires.

Possibly—as a last resort—"insolational whirlwind" would be a more appropriate name than dust devil. □



Typically, a dust devil is about several yards in diameter at the base and may narrow for a short distance upward, then expand again, like two cones, apex to apex.



Sea level has had its ups and downs through the ages; in the present era, it is climbing slowly

AS THE OCEANS RISE

BY STEACY D. HICKS

If all the ice in the earth's glaciers suddenly melted, the sea would rise an estimated 200 to 300 feet, and coastlines would move inland several hundred miles.

But no such disaster can take place, because the melting process requires thousands of years.

Variations in the level of the ocean over time spans ranging from several years to geological ages are very small when figured on a yearly basis. Over a man's lifetime, rises in sea level pose no threat to his safety either from the increased height or from coastal inundation. Over geological time spans, tremendous changes have and probably will continue to occur. These are significant, not only to future generations, but also to the present problems of beach erosion, shore and sea boundaries, elevations of the land and depths of the oceans, vertical land movements, and preservation of wetlands and coastal zone management.

Approximately 35,000 years ago, according to Drs. John D. Milliman and K. O. Emery of the Woods Hole Oceanographic Institution, the level of the sea was close to its present stage. Then, as more and more of the earth's total water supply became locked up in glaciers, the sea began to retreat. By 15,000 years ago, it was about 430 feet below its present level. Although there probably were some compensating vertical land movements, our Atlantic shoreline then was essentially well out at the edge of the continental shelf. Teeth of mammoths and mastodons and bones of the musk ox, giant moose, horse, tapir, and giant ground sloth have been found on the shelf, as have remnants of freshwater peat and pollen of land plants. It is even suggested that early man roamed the shelf before the water had completely returned to its present-day level. The Woods Hole Oceanographic Institution's research submarine ALVIN found ". . . what may be the remains of an oyster dinner on a former beach of Chesapeake Bay, a site that is now (141 feet) below sea level."

The sea began to rise rapidly from 14,000 until about 7,000 years ago. From 7,000 years ago to historical times, the sea has continued to rise, but at increasingly gradual rates. Numerous temporary stands have left their marks on the shelf in the form of submerged sea cliffs and terraces.

This has been the most recent of numerous major oscillations that have occurred through geological time spans. The findings were made by radiocarbon dating of shallow-water mollusks, calcium carbonate pellets, coralline algae, beachrock, and salt-marsh peat now found at various depths out on the shelf.

Monitoring sea level fluctuations with instruments is a fairly recent development. Here in the United States, the National Ocean Survey first began such measurements on a continuing basis in 1893 at New York City. Monitoring on the west coast began in 1898 at San Francisco; at Seattle it started a year later. On the gulf coast, the Galveston record is the oldest, dating to 1909. By 1940, 43 continuous sea level monitoring stations were in operation, and today there are 115 along the coasts of the United States.

During the past three decades of monitoring, the sea level of the Atlantic Ocean has risen from one to 5½ inches and on the Gulf of Mexico from ½ to 11 inches.

Steacy D. Hicks is a physical oceanographer in the National Ocean Survey.

Along the United States east coast north of Cape Hatteras, the sea has been progressively rising since 1928. A relatively steep rise was experienced between 1928 and 1946, followed by a tendency to level off until 1964. Since that time, the sea along the coast from Maine through Virginia has been rising at a very rapid rate. From 1964 to the present, sea level in this coastal area has risen an average of three inches.

The monitoring station showing the greatest rise in sea level for the United States is Eugene Island, La. From 1940 through 1970 the sea has risen there an average of .0297 feet per year, for a total of 0.9 feet. Since approximately .0033 feet per year is due to the addition of water from melting glaciers, this leaves about .0264 feet per year due to land subsidence. This abnormal land lowering is probably due to the weight of heavy sedimentation in the area, since it is located near the delta of the Mississippi River. The withdrawal of oil may also be a significant factor.

While sea levels were rising elsewhere, a number of locations in California, Oregon, Washington, and Alaska have shown a decrease since 1940. These include Los Angeles and Crescent City, Calif.; Astoria, Ore.; Neah Bay, Wash.; and Juneau, Sitka, and Yakutat, Alaska.

Juneau, Alaska, is the location of the monitoring station showing the greatest lowering of sea level. Here, sea level has dropped an average of .0428 feet per year from 1940 through 1970. Added to the amount for the addition of water from Greenland and Antarctic glaciers, we see that the land is rising at the tremendous rate of .0461 feet per year. The reason for this very large rise is that the land is rebounding from the release of weight due to the rapid melting of the local glaciers in the vicinity of Muir Inlet at the head of Glacier Bay.

Annual ups and downs of recorded sea levels are produced by a number of factors:

—When air pressure decreases, its weight on the sea is relieved, causing a higher level.

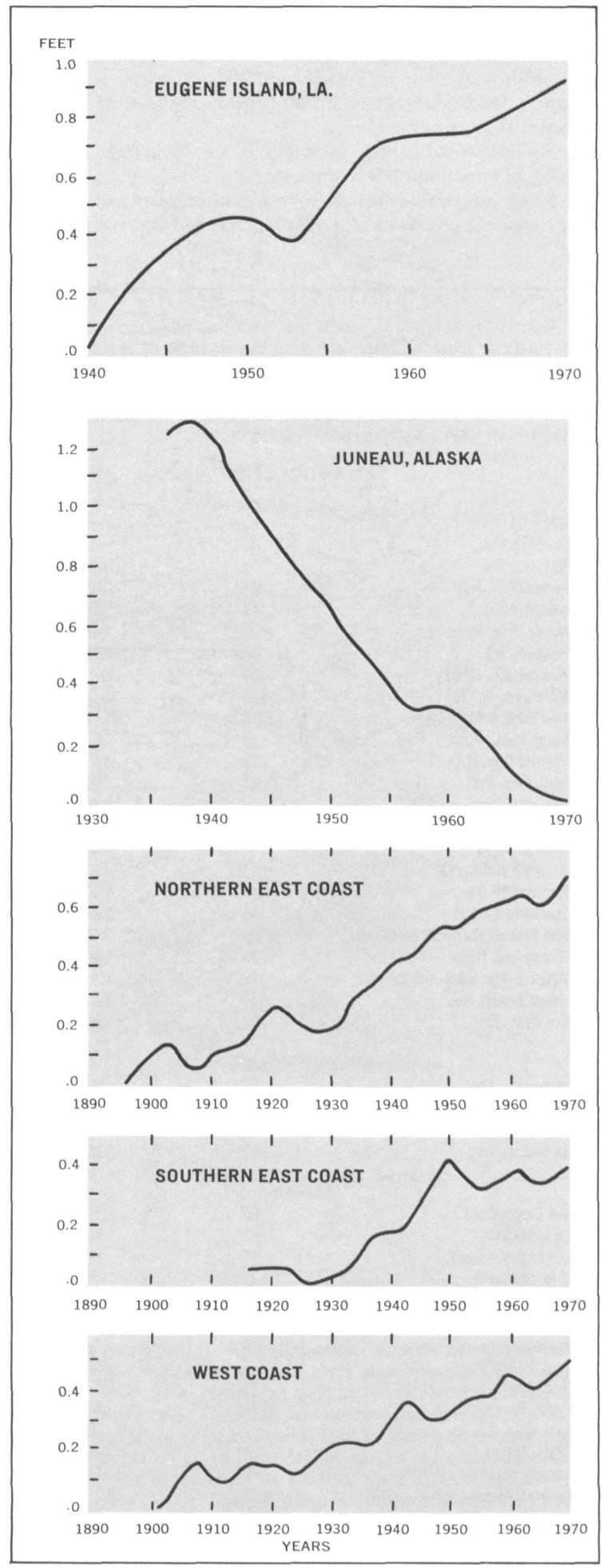
—When the wind blows predominantly in a direction which would cause the water to pile up against the coast, sea level is higher. Also, higher wind speeds at this direction would produce higher levels.

—When the water temperature is warmer and/or the salt con-

continued

"Helen! Quick! Start packing! The polar icecap is melting!"
Drawing by Robt. Day; © 1959
The New Yorker Magazine, Inc.

VARIATIONS IN OCEAN LEVELS



tent less, the volume of water of the same mass becomes greater and levels higher.

—When river runoff increases, so does the level of the sea.

—Finally, the slowing down of a northward-flowing coastal current off an east coast or a southward one off a west coast in the Northern Hemisphere would cause a rise in the level of the sea as recorded at shore locations.

As one would expect, these effects are completely reversible, causing, in turn, lower levels of the sea.

Small progressive changes over a span of years are caused by minor vertical movements of the earth's crust and the slow melting of glaciers, mostly the Greenland and Antarctic icecaps. Physical oceanographers are able to determine exactly how much of the yearly variations and the progressive changes can be attributed to each of the above causes at each location along our coasts.

For any rise in the level of the ocean, the shoreline will move inland a distance many times the amount of the rise. This is because the slope of the coastal zone is usually quite flat. Thus, even though sea level rises are quite small, movement of the shoreline is appreciable. This phenomenon is of great importance to beach erosion problems on the outer coast. Surf, the fundamental beach erosion agent, oscillates and breaks on this sea level base, seeking to gain equilibrium with the beach environment. When sea level constantly rises and the shoreline moves landward, the surf continues to erode, often necessitating protective measures such as groins, seawalls, bulkheads, and beach nourishment.

Since shore and sea boundaries depend on the location of this constantly moving shoreline, it is necessary to "fix" its location mathematically. Likewise, sea level itself needs to be "fixed" mathematically as a reference for land elevations and ocean depths. The definitions and methods of fixing these vertical boundaries and horizontal "zeros" are of great legal and engineering importance.

Comparisons of sea level graphs from monitoring stations closely spaced along a coast has enabled the National Ocean Survey to determine the amount of vertical crustal movement along the east coast of the United States. The observed rise in sea level along the coast of southern Maine is completely accounted for by the addition of water to the world's oceans from melting glaciers. Thus, it can be assumed that there is no significant vertical land movement in this area. However, with distance south toward Cape Hatteras, the observed rise becomes greater and greater than that due to glacial melting alone. The difference between the observed rise and the rise due to melting glaciers is the amount the land is subsiding. Actual calculations show that the rate of downward land movement increases progressively from zero in southern Maine to a maximum value of 0.084 inches per year in the Norfolk-Hampton Roads area. From about Cape Hatteras south through Florida there appears to be no vertical land movement of any consequence.

Probably the most timely aspect of sea level variations lies within the subject of coastal zone management. On quite flat areas behind barrier beaches or in the protected waters of sounds, embayments, and tidal rivers, the wetlands between high and low tide are often salt marshes. Their ecological importance and the efforts of citizen groups to prevent their destruction by landfill is in our news daily. Even with the preservation of salt marshes, however, danger continues to exist without very-long-range planning. Salt marshes so carefully preserved will be drowned in only a few generations with a continued rise in sea level. Although a salt marsh may be preserved in area, its landward boundary is usually marked by roads, railroad beds, and developed land. Thus, the salt marsh is not allowed to move inland naturally with the rise in sea level over prolonged periods of time. In other words, the mile-wide marshland will become only several feet wide and lose its characteristics when the tidal range impinges on a relatively steep railroad embankment. However, with long-range planning it could be possible to make provisions for landward migrations up the flatlands of an adjacent river valley, for example. For this reason, river basins, watersheds, and total area development—as well as tidal estuaries and the beach zone—must be considered in coastal zone management.

Sitting quietly in a boat just outside the surf zone as night begins, one can appreciate the efforts of earlier civilizations to personify the oceans. Swell can be imagined as pulse, and tide as breath, and the calm immensity of the depths as a primordial womb. But also one should imagine the ocean as actually growing and contracting, for man through the ages has detected a constant creeping of the sea surface where it intersects the shore. □

A list of key points where sea level has been monitored for 31 years or more follows, including the number of years during which data have been collected and the total sea level change from 1940 through 1970. Data for the Atlantic Ocean and Gulf of Mexico show a rise in the ocean level; those for the Pacific Coast show both rises and falls, as indicated.

Site	Monitored Years	1940 to 1970 Sea Level Change
ATLANTIC OCEAN		
Eastport, Me.	40	4.03 inches
Portland, Me.	58	1.86
Portsmouth, N.H.	44	1.86
Boston, Mass.	49	1.24
Woods Hole, Mass.	38	3.41
Newport, R.I.	40	2.48
New London, Conn.	32	2.79
Willets Pt., N.Y.	38	2.79
New York, N.Y.	78	3.41
Sandy Hook, N.J.	38	5.58
Atlantic City, N.J.	58	3.41
Baltimore, Md.	68	3.10
Annapolis, Md.	40	3.41
Washington, D.C.	39	3.10
Solomons, Md.	30	4.03
Hampton Roads, Va.	43	4.03
Portsmouth, Va.	35	4.03
Charleston, S.C.	49	2.17
Fort Pulaski, Ga. (near Savannah)	35	2.48
Fernandina, Fla.	32	1.55
Mayport, Fla. (near Jacksonville)	42	1.86
Miami Beach, Fla.	39	2.48
Key West, Fla.	58	.93
GULF OF MEXICO		
Cedar Key, Fla.	56	.62
Pensacola, Fla.	47	.62
Eugene I., La. (near St. Charles)	31	11.16
Galveston, Tex.	62	5.27
PACIFIC		
San Diego, Calif.	65	1.86
La Jolla, Calif.	46	2.48
Los Angeles, Calif.	47	— .62
Alameda, Calif.	31	.93
San Francisco, Calif.	73	2.48
Crescent City, Calif.	38	— 1.55
Astoria, Oreg.	46	— 1.24
Seattle, Wash.	72	3.10
Neah Bay, Wash.	36	— 1.55
Friday Harbor, Wash.	36	.93
Ketchikan, Alaska	52	.31
Sitka, Alaska	33	— 2.48
Juneau, Alaska	35	—15.81
Yakutat, Alaska	31	— 6.20
Honolulu, Hawaii	66	.31

FISH CITIES

A NEW SCHOOL OF DESIGN

Castoff junk is finding new uses in building planned communities for fish.

BY ANN WEEKS

DISCARDED STREETCARS, damaged drainpipes, derelict automobiles, concrete and rock rubble, wornout tires, even old stoves and refrigerators—materials with no further use on land—are being consigned to the sea to improve the fishing.

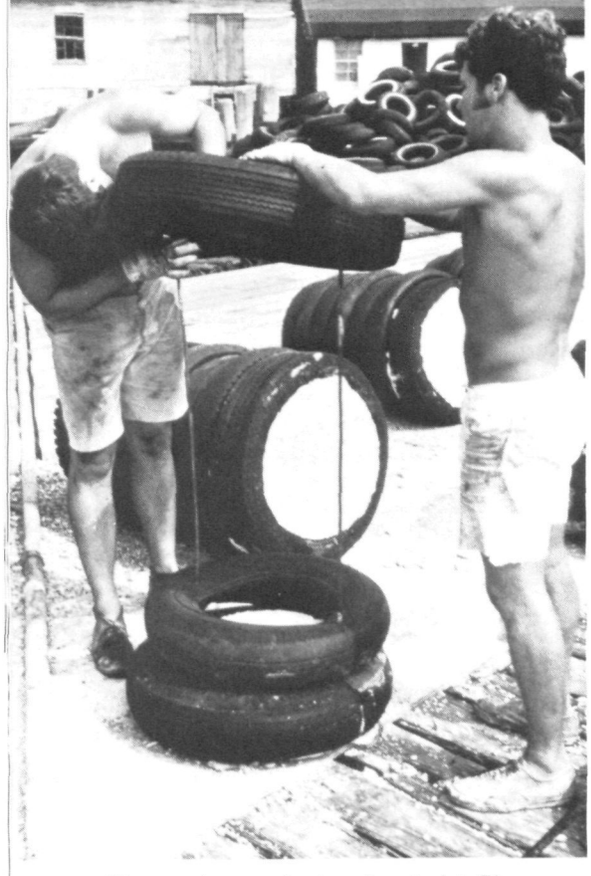
Over the past decade, saltwater anglers in U.S. coastal waters have been bringing in spectacular catches in regions previously untenanted by large quantities of fish—all because of the carefully planned disposal of a surprising array of items.

Along both coasts and in the Gulf of Mexico, a number of states have been sinking tons of such materials in barren stretches of the seafloor to form artificial reefs.

Underwater, the ocean claims them for her own and, in short order, blurs their outlines with thick layers of varicolored plant life and populations of sedentary animals such as barnacles, anemones, and seaworms. Bottom-dwelling molluscs and crustaceans find shelter in crevices and labyrinths, as do many species of small fish. Large fish converge on the new feeding grounds and soon—sometimes in a matter of weeks—a "fish city" is born. Within a year or two, to all outward appearances, man's discards have vanished, leaving only what looks like a camouflaged wreck, often swarming with commercial and sport fishes.

Sport fishermen were the earliest advocates of artificial reefs as a boost to their catches, citing as supportive evidence the rich fish populations congregating near ships sunk off U.S. shores. Marine biologists began to take an informal interest in the potential productivity of artificial reefs as long ago as 1950, following the establishment off Long Island, New York of the first recorded example of coastal marine-reef construction in this country.

continued



Tires make excellent reef material. They are placed in a stack of ten, fastened together with steel rods run through the stack, and weighted with cement in the bottom tire.

A really substantial effort to construct a fishing reef did not take place in the United States until 1953, off Alabama in the Gulf of Mexico. There the state authorized the construction of "snapper banks" made from junked auto bodies. Results were even better than had been anticipated. Phenomenal catches of snapper were brought in where none had been caught before, as were surprising numbers of grouper, jewfish, triggerfish, king mackerel, dolphin, cobia, and other species. The news soon spread to fishermen in other states, and construction of manmade reefs began in earnest.

Early efforts were enthusiastic but somewhat haphazard. Everything, including the kitchen sink, was pitched into coastal waters in attempts to duplicate Alabama's success. For several years, autos were the most popular choice as a reef-starter, as experiments increased in almost all states with coastal exposure. Some of the efforts were state-sponsored and on public view; others were undertaken by individuals who maintained a secretive attitude concerning location and results. In Alabama, additional snapper banks were added to the original one with continued success, using several thousand derelict cars.

Only after the various car-body reefs had been in place for three to five years did it become evident that auto bodies corrode and disintegrate in the ocean and, when they do, the displaced fish population disappears, too.

The passage, in 1957, of the Dingell-Johnson Federal Aid in Fish Restoration Act brought order and cohesiveness to the scattered effort to improve sport fishing in marine waters through the construction of artificial reefs. The Act made possible reef evaluation studies by several of the states, a more significant role in related investigation by marine specialists from state and Federal agencies, and direct participation in artificial-reef research by the Bureau of Sport Fisheries and Wildlife. (At that time and for the following 14 years, all Bureau activities were in the Department of the Interior. Since October 1970, when some of its responsibilities were transferred into the newly created National Oceanic and Atmospheric Administration, Marine Game Fish Programs have been under the direction of the National Marine Fisheries Service).

The Act established a broad program of financial aid to states and territories for the restoration and management of fish populations and fish habitats. It is a cooperative program between the Federal government and state and territorial fish and game departments. The states select and plan proj-

Sea bass gather around a newly formed reef of discarded tires. Bottom fishes are attracted to these structures because edible plants and animals collect rapidly on their surfaces.

ects, perform the work, and provide a portion of the funding. NOAA's involvement in the reef project is through the National Marine Fisheries Service and consists of research on reef biology. The Army Corps of Engineers, the Navy, and the Coast Guard operate in a consultive and regulatory capacity on questions concerning navigational and oceanographic subjects.

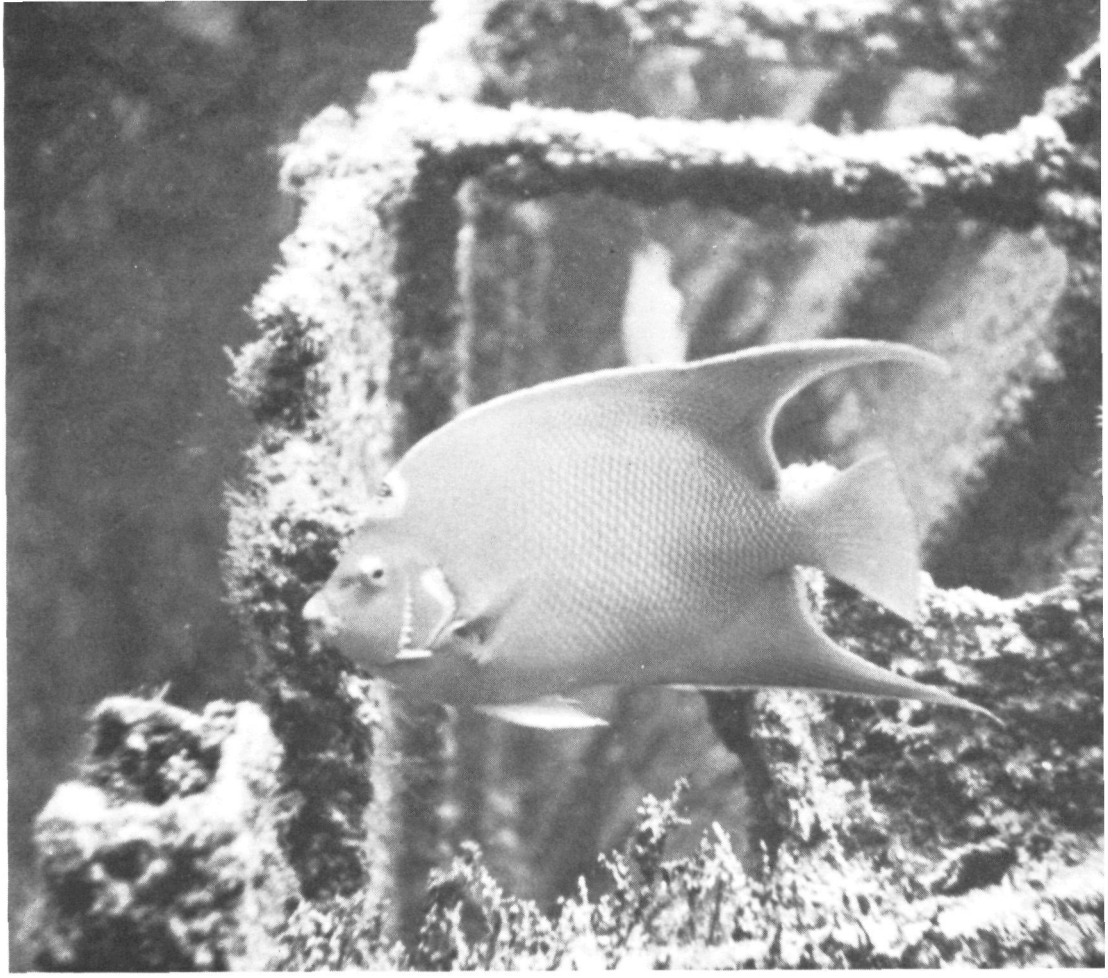
Marine scientists at the NMFS laboratory at Sandy Hook try to ascertain what types of material are most satisfactory for man-made reefs, the most practical physical form of such structures, kinds of substrate required, organisms that encrust the reefs, species and quantities of fishes attracted to artificial reefs, the balance among reef inhabitants, behavioral studies, and the economics pertaining to the establishment and maintenance of the manufactured reefs.

Over the past 15 years there has been a great expansion of state efforts to build a system of artificial reefs, increasing discrimination in materials used, more detailed analyses of results—and much better saltwater fishing. Presently taking part in the thriving program are Alabama, California, Delaware, Georgia, Florida, Hawaii, Maryland, New Jersey, New York, North Carolina, South Carolina, Texas, Virginia, Guam, and the Virgin Islands.

Some of the experiments have been successful from the start; others have failed—but even the failures have served the purpose of revealing the pitfalls to be avoided in building reefs. In California, for instance, six wooden streetcars were placed on the seafloor in 1958, a mile offshore from the Redondo Beach-Palos Verdes coastline on a bare sandy bottom. Preliminary biological surveys in the region had shown a sparse population consisting of a few invertebrates, 11 sanddabs, and one ray. Forty-two surveys during ensuing months showed thousands of fishes living in and around the streetcar reef. Spawning species included kelp and sand bass, blacksmith, white seaperch, pile perch, and bluespot and blue-banded goby. But millions of marine boring worms also were attracted to the feast of wood in the streetcar frames, and by 1961 the reef was a pile of rubble.

California had better results with quarry rock and concrete shelters. In the course of their artificial-reef investigations, state surveyors made the incidental discovery that the underwater structures supporting oil-drilling towers off Santa Barbara and Ventura Counties formed remarkably good bases for marine plant beds, which in turn attracted large numbers of inshore species and pursuing deep-sea predators.

Hawaii favored concrete box-like structures and auto bodies in many of its artificial reef projects, with mixed success. One of two concrete reefs placed in barren areas off Oahu showed an enormous increase of fish (1910 percent) in its first year of existence; the other had an insignificant gain (4 percent), which was blamed on its proximity to a natural reef habitat. Observers soon realized that, almost invariably, an artificial reef will not draw marine populations away from nearby natural reefs.



A queen angelfish investigates a reef created from three derelict ships.

A large auto-body reef begun in Maunalua Bay, Oahu, in 1960 fared well, evidently because new wrecks were added regularly to the original lot, the selected site was on hard rock bottom, and the frames were anchored by heavy concrete slabs. By 1963, 916 stripped auto frames covered some 13 acres of the seafloor, and surveys by the Fish and Game Commission revealed an increase in fish, from 36 pounds per acre before the reef was established, to an astonishing 1,542 pounds per acre afterward.

As early as 1955 the Texas Fish and Game Commission began construction of small, shallow reefs of oyster shell on mud bottoms in coastal bays. Within a few years 250 acres were devoted to these reefs. The shell reefs not only improved fishing prospects off Texas, but rehabilitated the oyster industry along the coast. In 1958 and 1959, more than 2,000 burned shells of cars were sunk off Port Aransas, Port Isabel, and Freeport. While they lasted, the reefs lured innumerable food and game fish to those regions, including large red snappers, Spanish and king mackerel, jewfish, wahoo, and cobia. The structures began to sink into the sand in 1960, and in the following year were totally destroyed by a hurricane. In 1962, a new start was made in the same regions and near Galveston, but the material used consisted of large-sized heavy pipes made of clay and concrete, cabled together in stacks of three. These structures proved durable and otherwise satisfactory, and soon numerous fish communities occupied the reefs. Texas fishermen were gratified by excellent catches of sportfish such as snapper, gaff-top catfish, silver trout, golden croaker, and grouper.

Following her pioneer efforts with reefs in the early 1950's, Alabama continued the construction of auto-body "snapper banks" in a variety of sites, with predictable results. After the reefs were established, fishing became extremely good, then catches began a very gradual decline as the auto bodies corroded and disintegrated. A few of the reefs, however, remained productive for several years. The largest of the state's artificial reefs—called a "fishermen's paradise"—consists of a sunken drydock lying 14 miles off Mobile in 70 feet of water. The 300-foot long, 150-foot wide reef was sunk in July 1959 and promptly "lost" for 10 months. When it was rediscovered, the reef had had time to build up into an incredibly rich source of gamefish which, according to surveyors, seems to replenish itself a few days after fishermen have removed large numbers of the resident population. Common in catches are red snapper, bullhead, sheepshead, grouper, and enormous jewfish. Alabama's conservation authorities have tested many kinds of substrate and sunken material over the years, including scrap metal, concrete pipe, scrap culvert pipe reinforced with steel, even a steel lifeboat.

continued

Most of the experiments proved highly satisfactory to Alabama anglers, whose state contains no natural reefs.

Florida offers encouragement and assistance to various civic and sportsmen's groups, but is not itself in the reef-building business, in part because the presence of many natural reefs in Florida waters reduces the need for artificial ones. A number of reefs made of various substances have been emplaced in coastal waters by citizens' efforts. These include a true junkyard reef off St. Petersburg, consisting of 60 car bodies, one bus, 12 stoves, 12 assorted engines, 40 refrigerators, 30 truck bodies, and two tons of odds and ends of metal and cement. These were fastened together with cables and clamps, and the lot was dumped into 28 feet of water on a sandy bottom 2,400 feet offshore. Official inspections of conditions underwater have not been made, but fishermen report good sportfish catches where none were made before the reef was installed. A fishing reef of concrete blocks was successfully established off Cocoa Beach in 1964.

A reef project begun in 1962 off St. Petersburg, Florida, proved to be the forerunner of one of the most effective and favored styles of reef construction in the 1970's—discarded tires stacked on metal rods and weighted at bottom with concrete. Periodic inspections have shown that the units do not disintegrate, form a satisfactory base for encrusting animals, and attract copious quantities of small and large fish.

Conservation departments and fishery scientists in Maryland, Virginia, Georgia, the Carolinas, New York, and New Jersey have created numerous artificial reefs of mollusc shells, discarded autos, concrete rubble, damaged pipes, automobile tires, and the like. The presence of many "accidental" artificial reefs formed by shipwrecks off the Long Island and Jersey Shore somewhat mitigated the need for additional manmade fishing grounds off the New York-New Jersey coastlines. Both states have devoted considerable time to monitoring marine populations in the vicinity of wrecks.

One outstanding project was undertaken by the New York State Department of Conservation in 1962 off Fire Island. This largest manmade reef measures one mile by one-tenth of a mile in water about 70 feet deep. Is was built with 26,500 cubic yards of selected building rubble, 500 three-tire units, seven wooden barges, and one steel barge. The reef is used by fishermen 12 months a year, and charter boat captains and private boat owners report the fishing good to excellent. Some of the species taken include cunner which make up about 40 percent of the population at the reef; black sea bass, 17 percent; ocean trout, 12 percent; tautog, 11 percent; and scup, 9 percent. Various other species constitute the remaining 11 percent. The samples were taken periodically in fish traps during 1969 and 1970. A total of 548 lobsters also was caught where virtually no fish had been taken prior to the reef emplacement.

The Virgin Islands was the site, in 1960, of a different kind of artificial-reef experiment—different in the sense of participating organizations, material used, and results. Under the support of the Dingell-Johnson program, the National Science Foundation, the National Park Service, and the government of the Virgin Islands joined forces to construct a reef made of 800 concrete blocks in a tunnel arrangement 30 feet down in Lameshur Bay. Two years after it was established, the reef was explored by marine scientists whose findings were surprising: the number of fish species collected—55—was unusually high, many times higher than would be found ordinarily in seagrass beds in the region; a comparison of the organisms in the artificial reef with those found in natural reefs showed that the former concentrated 11 times more fishes in weight per unit area than the latter. Biologists also found that colonization of the Virgin Islands manmade reef was slower than in other areas, such as southern California.

The many cooperative efforts between the states and the Federal government by late 1971 had resulted in the construction of some 150 artificial reefs off U.S. coastlines. By and large, reaction to the structures has been favorable.

Detractors have been few, and their complaints have largely been confined to two topics. The first—from those concerned about deterioration of the ocean environment—is that the dumping of any kind of trash into the sea must be harmful to marine ecology. The second—by commercial fishermen—is that artificial reefs sometimes interfere with nets and gear, and that certain reefs usurp commercially valauble fishing grounds.

Such fears have been allayed, in the first instance, by hard evidence—collected over a considerable period of time by state and Federal scientists—that no untoward effects stem from the materials used in underwater artificial reefs, and by the knowledge that great vigilance constantly attends the installation of reefs. As to the second complaint, the submerged reefs did cause fishing difficulties on occasion, but mostly in the early stages before the necessity for strong anchoring devices and for limitations on the height of installations became apparent.

Fifteen years of research have resulted in rigid guidelines for today's submerged structures. Preliminary surveys of selected sites take place as a matter of course, and permits must be obtained in many cases from state authorities, the Navy, the Coast Guard, and the Army Corps of Engineers. The National Marine Fisheries Service also participates in surveys to help ensure that none of the artificial reefs encroach on commercial fishing grounds and that the character of new fishing reefs does not interfere with commercial fishing operations.

Richard Stone, NMFS reef study project leader, is working with the Tidewater Artificial Reef Association of Virginia and the U.S. Navy to sink 158 surplus naval landing craft to form two artificial reefs in waters off Norfolk in early 1972. When emplaced underwater, the two manufactured reefs will form the largest such structure in the world, covering about 60 acres. The installation is expected not only to provide Chesapeake Bay fishermen with increased catches, but to furnish marine scientists with an extensive underwater laboratory for the gathering of long-term data. NMFS biologists investigating the reef will seek to answer the question of whether fish are merely attracted from natural grounds to artificial reefs, or whether rates of reproduction increase because of the presence of a protective "megalopolis" for fish populations.

NMFS research on artificial reefs has been conducted from the Northeast Coastal Research Center's laboratory at Sandy Hook, N.J., but will be moved to the Beaufort, N.C., Coastal Fisheries Center early in 1972. Observations of reefs in the middle and south Atlantic coast will continue from the relocated headquarters. Related work will be continued at Sandy Hook to determine the effectiveness of reef-like structures placed in dredged areas.

In general, NMFS researchers favor discarded rubber tires as the material best suited to artificial reef formations. They point out that used tires are almost indestructible, and that bottom fishes are attracted to the structures, evidently because edible plants and animals collect rapidly on the surfaces and because the stacks of tires provide many sheltering places. Wornout tires have the additional advantage of costing little to transform into practical undersea structures. Customarily, the tires are placed in a stack of ten, fastened together with steel rods run through the stacks, and weighted with cement placed in the circumference of the bottom tire. The weighted bottom causes the stack to fall into an upright position when dropped into the water. The most useful arrangement appears to be several rows of the tire stacks placed a few feet apart in at least 50 feet of water. NMFS researchers installed this type of artificial reef off Pacific Reef, near the Pennekamp State Park in the Florida Keys, in January 1972, and later—in one of the projects completed under FLARE (Florida Aquanaut Research Expedition)—compared marine populations inhabiting the tire reef with those in a natural reef nearby.

The NMFS laboratory at Pascagoula, Miss., and its Southwest Fisheries Center at La Jolla, Calif. have been engaged for some time in experimental work based on a variation of the artificial-reef theme, in the form of devices that attract fish at midwater and at the surface. The studies grew out of the age-old knowledge that many fishes aggregate under and near all kinds of floating objects. NMFS researchers have realized satisfactory results with a pyramid-shaped platform made of a framework of pipes over which plastic material is stretched. They fasten the contraption into place with buoys and then monitor the fish species that take up residence beneath it. In a test by Pascagoula researchers, an experimenter fished close to one of the pyramids at depths of 30, 60, 90, and 120 feet, then spent an equal amount of time fishing at similar depths in open water away from the platform. In one week, he caught 118 fish while trolling near the reef and only 18 fish trolling in open water. The device is considered successful, the basic idea has been

This barge and nine more were submerged to form one artificial reef. Fisheries Service studies indicate that reef materials should be large and bulky, with plenty of large cavities and entrance holes.

adopted, and future work will be devoted to refinements.

As a result of the hundreds of experiments conducted in all the coastal states by numerous scientists and fishermen over the past two decades, these conclusions can be drawn:

☐ Artificial reefs, properly located and constructed, serve as a concentration point for marine species in otherwise barren sites.

☐ Units should be large and bulky, with plenty of large cavities and entrance holes. They should be piled up so as to rise well above the bottom profile over a large area, but not high enough to interfere with ship navigation or commercial fishing gear. Buoys should mark most artificial reefs.

☐ Reef material should be as durable and as care-free as possible. Auto tires and some sunken vessels offer many advantages; concrete shelters or large quarry rocks have proved highly satisfactory; auto bodies and other thin-metal objects are successful, but temporary, havens for fish since these disintegrate quickly; untreated wooden structures have short-lived value because of marine borers; low-profile materials (stone and concrete rubble) are not satisfactory.

☐ Artificial reefs should be constructed in barren areas of the seafloor, away from natural cover; a hard bottom is preferable (in some experiments, steel or creosoted pilings bases have been emplaced under the reef structure).

☐ The most suitable depth for constructed reefs depends largely on the character of the region under consideration. Although reefs have been established at depths from 10 feet to 125 feet, experience indicates that sites probably should be at 50 feet or more. Avoidance of damage by stormy surf must always be a major consideration.

☐ Physical and biological surveys are highly advisable before reefs are installed. State and Federal government regulations should be observed.

☐ Reefs should be situated outside navigation lanes.

☐ Construction materials should be non-toxic, non-metallic and non-floatable.

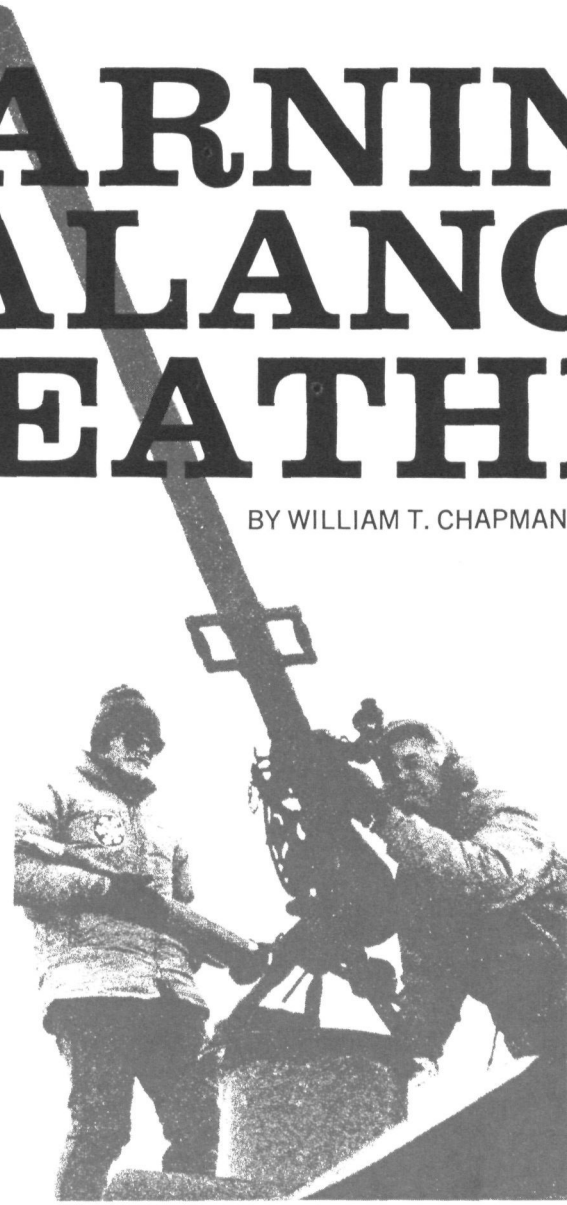
☐ Fishing restrictions should be established at the outset of construction to permit a newly built reef to mature.

Artificial reef construction, though limited in its developing years—roughly 1950 to 1970—can be expected to increase considerably during the current and next decade. Prospects for sport fishermen, therefore, can be said to be looking up, to bigger and more varied catches of marine fish in progressively more accessible regions. ☐

Massive avalanche plunges down a steep slope of Mt. Superior into Little Cottonwood Canyon, Utah.
Forest Service Photographs

WARNING! AVALANCHE WEATHER

BY WILLIAM T. CHAPMAN AND FRANK REANIER



Forest Service snow rangers use rifles to trigger slides before they reach dangerous proportions.

National Weather Service offices are providing vital assistance to a Forest Service safety program.

THOUGH SPRING has come to some parts of the United States, in others the avalanche alert continues.

On mountain slopes, the wet snows of springtime, followed by warming temperatures or rain, create a serious hazard. An avalanche could be triggered by the snow's own weight—or by a single skier.

Snow avalanches occur by the thousands every year in mountainous country. Large or small, they can have tremendous force and pose a threat to travelers, skiers, and snowmobiles.

In a single month—January 1971—499 snow avalanches were recorded along the highways and in ski areas of Washington's Cascade Mountains. The toll was high—15 people buried, six injured, five killed. The loss of life might have been greater without the U.S. Forest Service's snow avalanche forecasting and control program in developed ski areas.

Working with the Forest Service are two National Weather Service Forecast Offices in the Western Region—Salt Lake City and Seattle.

Snow avalanches are complex phenomena and are not so well understood that all of them can be predicted accurately. To achieve better understanding, the Forest Service established an Avalanche Study Center at Alta, Utah, under the direction of the Wasatch National Forest. Early research and guidance by Dr. Edward LaChappelle, of the University of Washington's Department of Atmospheric Studies and Alpine Research, was used in developing the Avalanche center. The center conducts research to learn why and how snow acts as it does under varying conditions. It also serves as a local warning center as the avalanche danger increases.

According to Dr. LaChappelle, "avalanches are caused by structural instability in the snow cover. The concept of an avalanche forecast is predicated on the assumption that instability can be recognized and interpreted."

A number of weather factors contribute to the instability of snow. Avalanche forecasting methods take into account wind, temperature, snowfall, precipitation intensity, new snow depth, crystal type, density, and settlement. The depth and consistency of the existing snow cover also are important in estimating the avalanche potential.

The Salt Lake City Weather Service Forecast Office provides avalanche weather support services for the steep slopes of Utah's Wasatch Range, where there are a number of heavily used ski areas. But the main danger is on the highways leading to the resorts; these roads lie in canyons subject to heavy winter snowfall.

Each day, from early December through April, the Salt Lake City office prepares morning and evening forecasts of snowfall, wind and temperature expected in the ski areas. These are provided to the Avalanche Study Center and the Utah Travel Council, which makes radio and television ski broadcasts daily. The Study Center also monitors weather trends through its drop on the Salt Lake City NOAA Weather Wire teletypewriter service. Special advisories associated with all major storms are relayed by direct telephone consultation to the Chief Ranger in the Avalanche Study Center. These advisories contain information on expected heavy snowfall in excess of 12 inches in 12 hours, conditions of snowfall (powder or wet), and direction and duration of winds between 10 and 20 thousand feet.

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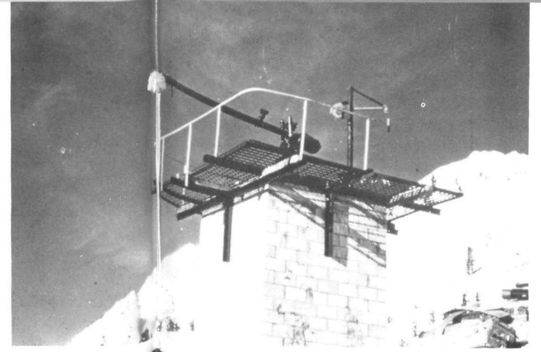
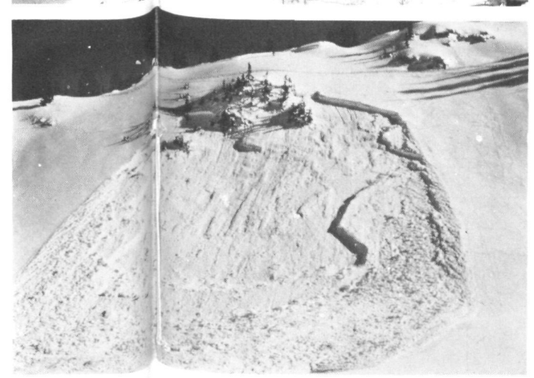
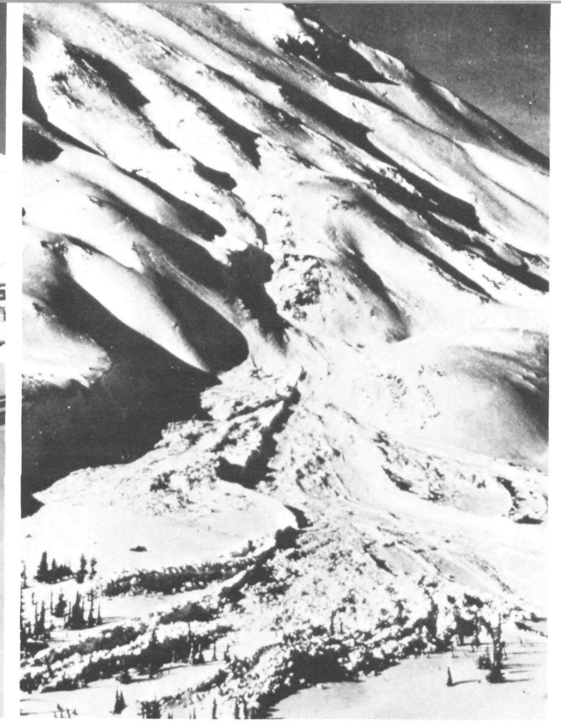
William T. Chapman is meteorologist in charge at the Salt Lake City Weather Service Forecast Office. Frank Reanier is principal assistant at the Forecast Office in Seattle.







(Opposite page, left) Two large avalanches lie across old railroad tracks at Stevens Pass, Wash., near the scene of the greatest U.S. avalanche tragedy, in which 96 persons died. (Opposite page, top) Digging out a buried car. (Below) Hard slab avalanches are characterized by large blocks of snow. (This page, top left) Mounted avalanche gun. (Below) Slab avalanches leave well-defined fracture lines. (Left) The path of a wet avalanche.

Daily snowfall and temperature observations from the U.S. Forest Service, along with reports from ski resort areas, are used to refine special forecasts for the Alta Center.

Any mention of an avalanche or potential avalanche in the heavily traveled resort canyons is taken very seriously by the public. Such announcements signal the closing of canyon highways, and become headline news for radio and television.

Therefore, a system has been established in which all warnings are issued by the Forest Service avalanche experts, after careful coordination with highway and police officials. Though the Weather Service is directly involved, its role is primarily one of weather forecast support. After an avalanche warning has been issued, the Salt Lake City weather office relays the warning over the local NOAA Weather Wire.

The Weather Service Forecast Office at Seattle issues special weather alerts for avalanche control, under a cooperative program with the U.S. Forest Service (Snoqualmie National Forest). These advisories warn of heavy snow, rapid warming, strong winds, and other weather factors affecting the stability of the snow cover. In support of this program, the Washington State Highway Department and snow rangers in ski areas provide local weather observations. The special weather warnings normally are not issued to the public, but during the winter of 1970-71 and again this year the avalanche potential became so extreme that avalanche warnings were issued to the general public for winter sports activities outside of the developed ski areas. In that season, Paradise Valley on the south slope of Mt. Rainier measured a record snowfall of 1027 inches.

Specially trained snow rangers conduct safety programs in avalanche-prone areas under the Forest Service's jurisdiction. Samplings are taken frequently to determine layer stability within the heavier snowpack of dangerous areas. The rangers dig snow pits to examine the temperature and strength profile of various snow layers from earlier storms. Sometimes, they simply ski across a known avalanche path to test the snow's stability.

Whenever possible, the rangers lessen the avalanche buildup by mechanically triggering slide areas before they reach dangerous snowslide proportions. If a high avalanche potential develops rapidly, or a severe snowstorm is forecast to increase avalanche potential, the snow rangers use the explosive impact from a 77-mm. or 105-mm. recoilless rifle to trigger controlled slides, minimizing the danger to avalanche buildup.

Snow avalanches are of two principal types—loose snow and slab.

A loose snow slide starts at a point, or over a small area, and grows in size, the quantity of snow involved increasing as it descends. It moves as a formless mass, with little internal cohesion in the snow. Such slides usually occur with large accumulations of dry powder snow on rather steep, smooth slopes.

Slab avalanches, on the other hand, start when a large area of snow begins to slide, leaving a well-defined fracture line where the moving snow breaks away from the stable snow. Though slab avalanches vary, there are two main types: the soft slab and the hard slab. Soft slabs break or slide away from a fracture line, but take on the general appearance of a loose snow avalanche because of poor cohesion in the snow body. The hard slab is made up of strongly bonded snow with sufficient cohesion to hold its form, which is characterized by angular large blocks or chunks of snow in the sliding debris.

Many of the soft slab avalanches occur during or immediately after relatively heavy snowfall and involve only the new snow. They are the most common avalanche hazards associated with heavy winter storms. Following a heavy snowfall, the danger from slides of soft slab decreases with the passage of time as the snow settles and stabilizes. When the heavy snowfall occurs with temperatures near freezing, slide danger will last several hours; but when snowfall occurs with temperatures near zero, slide danger may last a week. Almost all serious accidents are caused by slab avalanches.

The slope profile contributes to the formation of the more dangerous avalanches. Most slides, especially loose slides, develop on steep slopes averaging from 30 to 60 degrees in elevation. Often, a broad convex curve in the slope profile is located higher up the slope just below the ridge. On broad slopes with heavy snowfall, a massive area of snow with extreme instability usually lies in the convex curve zone. Strong, turbulent winds blowing across the high ridgeline increase the snow accumulation and impact the snow into a bond of heavy, hard slab. As the area grows heavier with additional snow accumulations, the thick slab layer changes, developing various stress points and high surface instability. Also, metamorphic changes usually take place in sublayers or at the ground in the bonding layer of earlier dry powder. Air pockets form below the hard solid slab, and produce a hollow sound when the slab is struck. Large, hollow-sounding slabs are very unstable and dangerous. Lateral breaks or cleavages develop explosively across the high tension zones of large slabs when triggered externally. Such breaks lead to very serious avalanches of mammoth proportions. The large slides run across the bases of steep canyons, imperiling major highways and closing them to traffic.

Rough ground cover, such as large rocks, trees, or heavy brush, helps to anchor snowfall on mountain slopes. Smooth grassy slopes form a poor bonding surface for new snow. New snow—especially dry powder snow—falling at a rate of one foot in 12 hours can rapidly increase avalanche danger where the slope averages from 30 degrees to 60 degrees in elevation.

Snow crystal types are another important factor in avalanche formation. Small crystals—needles and pellets—and the light, fluffy crystals associated with low-temperature storms create more dangerous loose slide conditions than large, wet, star-shaped crystals. The smaller dry crystals do not bond tightly together, and the snow persists in an unstable condition under continued cold temperatures. The small-crystal type—referred to as dry or fine powdered snow—is preferred by snowmobilers and skiers because of its almost frictionless character.

Wet snow, made up of large, star-shaped crystals, occurs in spring when temperatures are near freezing or in winter when moisture is abundant. After a wet snowfall, if the temperature becomes colder and the air drier, then the large wet crystals settle and stabilize. However, if temperatures rise or rain occurs, moisture from snowmelt or rain percolates downward and lubricates the snow and its earlier bonding surface. Instability develops rapidly, and conditions are ripe for a wet loose avalanche. Then, the weight of additional snowfall—or of a skier or a snowmobile—may set off numerous slides. This wet loose type of avalanche is more likely to occur in the Cascades or Sierras because of their proximity to storms from the warmer, moist Pacific Ocean.

Strong winds, especially those associated with a strong upper jet from the north or northwest, cause drifting and blowing of snow, adding to accumulations on lee slopes. After a heavy snowfall, this can markedly increase the threat of a slab avalanche. Strong northerly winds during a major snowfall also form massive cornices at ridge lines, which gradually build outward toward the lee side. Massive cornices in themselves can become very heavy and unstable. Persistent high winds—in excess of 40 knots—break off large segments of unstable ridge cornices. Falling cornices often trigger major fractures in large, deep, hollow-sounding slabs along the tension zone of a steep slope. In the Alta, Utah, area, such slopes normally face to the south. South-facing slopes, with a heavy layer of unstable snow, are the most dangerous in the spring and on sunny days. But any rapid changes in weather conditions—such as high winds, rapidly rising temperatures, heavy snowfall—cause major snowpack adjustments which may affect stability and create an avalanche potential.

A great deal more remains to be learned about snow and avalanches, not only for the safety of winter sports enthusiasts but also to meet the needs of power companies, railroads, building contractors, and mining and irrigation companies.

At the present time, Seattle and Salt Lake City are providing the main weather support to avalanche warning programs in the Western Region. As winter activities expand and extend into undeveloped mountain areas, the demand for this type of program can be expected to increase. □

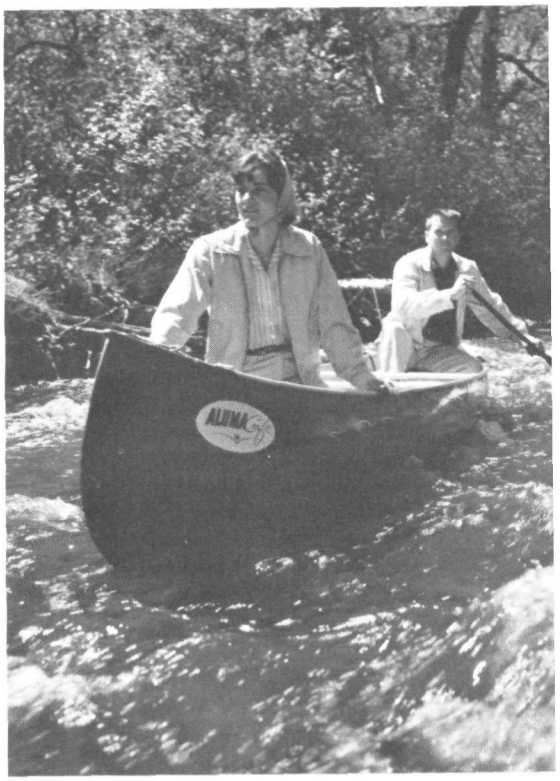
When the fleet takes to the water in spring, so do NOAA's nautical charts and weather services.

BY JOHN HANNA

SMALL BOATS ON THE GREAT LAKES

Sailboat racing is one of the major forms of recreation on the Great Lakes

Corps of Engineers photograph



(Left) The small boat basin of Chicago Harbor is thronged with moored pleasure craft. (Above) The Minnesota-Ontario Border Lakes system is popular with canoeists.

An annual Great Lakes phenomenon—the opening of the boating season—is about to take place with a fantastic fleet composed of everything from rubber rafts to posh yachts all hitting the water almost simultaneously. This multiple launching sends ripples back and forth across the Lakes which signal the coming of summer. And summer on the Great Lakes is something else!

Lacy fringes of frozen water still stubbornly ring the Lakes' shores and bays, but where just a few months ago marinas were quiet and peaceful with row-on-row of silent, snow-covered boats and empty, ice-filled slips, the sound of hammer and electric sander now permeates the air. Soon harassed marina operators will begin working 16 to 18 hours a day, seven days a week. In thousands of Great Lakes homes, charts are being spread out, probably on the kitchen table, to study and plan cruises even while traces of snow still patch the ground. Power Squadron and Coast Guard Auxiliary spring boating classes are over and brand-new, certified mariners are set to try their newly acquired skills. Many are beginning to think about trading the old boat for something a little bigger—a little better.

Paradoxically, with the coming of balmy summer days comes danger in a variety of forms for the unwary mariner and the Coast Guard's working day lengthens as the boating season progresses. Distress calls, usually from someone out of gas but sometimes more serious, usually peak in July or August. Boating safety agencies stress that recreational craft should carry the latest nautical charts and water level information and that skippers should heed marine weather broadcasts, but there will always be those few who say, "I don't need that stuff; I know these waters like the back of my hand." Last year, more than 2,100 search and rescue missions were conducted by the U.S. Coast Guard on the Lakes.

Fishing, water-skiing, skin diving, sailboat racing, predicted-log races for power boats, cruising to distant, secluded harbors or just "getting out" on a Sunday afternoon occupy the leisure time of the owners of almost two million craft registered in the eight Great Lakes States. Michigan with nearly 2,500 miles of Great Lakes shoreline, plus hundreds of inland lakes and nearly 90 natural or improved harbors, leads all Great Lakes states and the nation with over 434,000 registered boats. According to 1970 U.S. Coast Guard statistics, boat registrations for other Lakes states are: New York, 428,000; Wisconsin, 312,000; Minnesota, 285,000; Ohio, 212,000; Illinois, 172,000; Indiana, 130,000; and Pennsylvania, 106,000.

Naturally not all sail the Lakes, but the percentage is significant even for a State like New York, which touches Lakes Erie and Ontario, the St. Lawrence Seaway and the Atlantic Ocean. Expo '67 added to the recreational traffic when east coast boaters realized they could sail inland to Montreal and that those routes provided access to the Great Lakes. Since then, many popular cruises have been developed. They have proved so popular, in fact, that New York State has published several chart booklets and guides. The charts were copied, with permission, from the charts of the National Ocean Survey and its Lake Survey Center. The state's publications, however, are not kept up-to-date as are NOAA's and each contains a statement that for actual navigation, official charts should be obtained. The cruises cover the areas from New York City up the Hudson River, then west at Troy along the New York State Barge Canal to Lake Erie or Lake Ontario via the Oswego Canal. Or they continue north through the Champlain Canal to Lake Champlain and on to the St. Lawrence River below Montreal. From there, boaters can cruise up the St. Lawrence to Lake Ontario, then across the Lake to Oswego and back into the barge canal system.

Among the other many popular cruising areas on the Lakes are the Apostle Islands in western Lake Superior, Georgian Bay and North Channel in Lake Huron, and the scenic Minnesota-Ontario Border Lakes system northwest of Lake Superior, which is especially enjoyed by canoeists.

A few of the many other possibilities open to the venturesome recreational craft operators are Canada's Trent-Severn Waterway joining northeastern Lake Ontario with Georgian Bay on Lake Huron; the Straits of Mackinac and historically famous Mackinac

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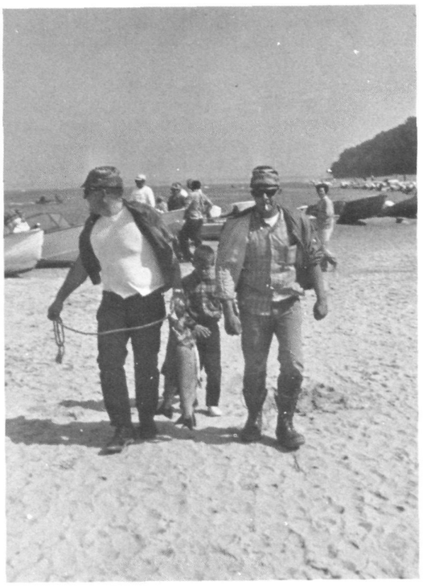
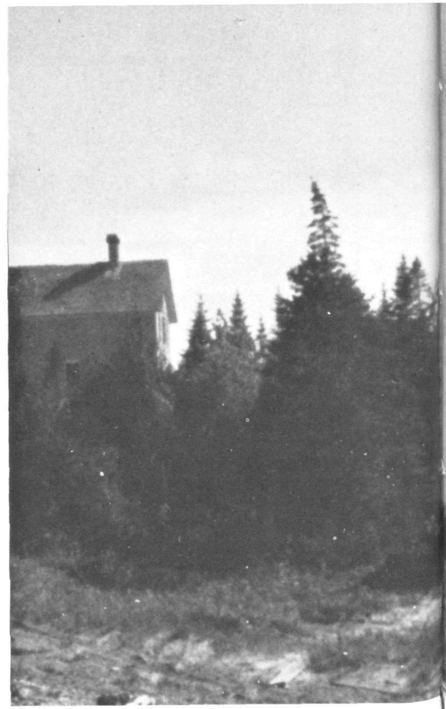


(Above) Coho and chinook salmon attract thousands of fishermen to the Lakes. (Right) The Mackinac Island races are major annual events. (Below) More than two million boats are registered in the states bordering the Great Lakes.

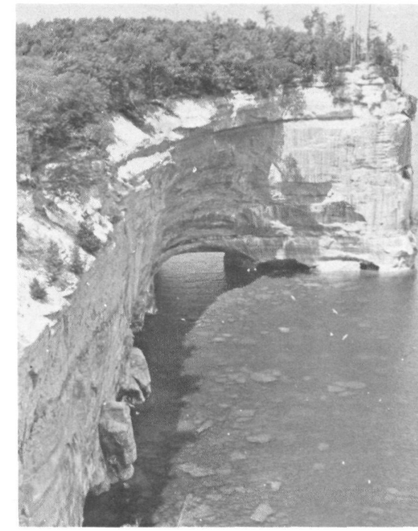
Photo by J. Miner, Monroe Evening News

Michigan Tourist Council Photograph



Great Lakes Foundation photograph

(Left) Abandoned lighthouse on South Manitou Island, Lake Michigan. (Below) Rocky promontory on Lake Superior.



Michigan Department of Natural Resources Photograph

Island; the Beaver Island group in northern Lake Michigan and the many excellent harbors along Michigan's western shore; the island area in western Lake Erie; Canada's Rideau Waterway joining eastern Lake Ontario with the Ottawa River to the North; and Lake Winnebago in Wisconsin, which is joined to Green Bay and Lake Michigan by the Fox River.

Among the major Lake-area boating events each year are the unlimited power boat races on the Detroit River. They are very popular, and tens of thousands of people line the shores to see these sleek craft with their powerful engines reaching speeds of over 180 miles per hour on the straightaways.

Sailboat races, although obviously not as fast, are just as exciting to many, particularly for those competing. Probably the high point of the Great Lakes boating season is attained during the two Mackinac races, held a week apart. Many boats compete in both races, which alternate starts annually.

The Chicago to Mackinac race begins in the Lake Michigan waters east of the Windy City, with the finish line near the harbor on Mackinac Island at the northern end of Lake Huron. It covers about 335 miles and usually takes less than two days, depending on weather conditions. A severe storm several years ago decimated the fleet, with numerous dismastings and many boats forced to seek shelter. An ocean-racing sailboat skipper trying his luck for the first time was quoted in newspapers as saying that it was the roughest water he'd ever seen anywhere. The basis for his statement probably was the fact that wave periods on the lake are somewhat shorter than those on the ocean, making choppy seas.

The Port Huron to Mackinac race, sponsored by Detroit's Bayview Yacht Club, is not as long as the other, but usually draws more entries. The race will be longer in 1972 than it has been for some time. The previous route was straight north up Lake Huron and then northwest to Mackinac Island. This year, they will race north-northeast to a sea buoy near the entrance to Georgian Bay, then west-northwest to the Island. The distance for the new route is about 300 miles. Also under discussion are proposals to combine the races; start at Port Huron and race to Chicago—a course covering over 600 miles.

The longest race on the Lakes at the moment is one started a few years back. Its course extends from Sault Ste. Marie to Duluth, east to west across the entire length of Lake Superior, a sailing distance of about 400 miles.

Besides the big races that have boats of different classes according to length and sail area, there are numerous shorter "one class" races and regattas, with something going on nearly every week during the season. In addition, many U.S. Power Squadron and U.S. Coast Guard Auxilary units conduct rendezvous, group cruises, and predicted-log races. The latter are becoming more popular each summer.

Boaters whose vacation time doesn't permit them to spend long periods cruising to an area have solved their problem quite nicely. They put their boats on trailers and haul them where they want to go. This form of boating has increased by leaps and bounds. Some even trailer their boats from faraway states in order to enjoy boating on the fresh water Great Lakes. Almost every state-operated or private marina has a launching ramp, and that's all that's needed to get to where the big ones are biting or to explore a craggy, uninhabited island. An added advantage to trailer-boating is that when the season ends you pay no haulout or winter storage charges. Just park your trailer alongside the driveway and you're ready for winter or for the first warm day in spring.

It is safe to say that there are hundreds, perhaps thousands, of wrecks dotting the floors of the Great Lakes. This is one of the principal reasons for the rapid growth in the sport of scuba diving. And to most skin divers it is a sport. The thrill of investigating a hulk which may be over a century old and collecting a few souvenirs is unsurpassed. Hardly a year goes by in which some lucky diver doesn't discover a nearly forgotten vessel, her anchor, nameplate, or other identifying piece of gear. Marine museums around the Lakes are always on the lookout for such finds to enhance their collections.

In the 1930's, rumor has it, a freight car loaded with new automobiles rolled off a Detroit River carferry. But, in spite of all recovery efforts, the freight car has never been found. Covered by mud at the bottom of the river? Washed downstream by the current? The dark, forbidding waters haven't given up their secret—yet.

Many ships which have vanished over the years will never be found, or at least not without special equipment. The maximum effective depth at which a scuba diver with conventional gear can operate is 150 feet. Water depths on the Lakes range from a maximum of 1,333 feet for Lake Superior to an average of 62 feet on Lake Erie. The great depths in many areas do limit the skin diver somewhat, but there are enough places where he can operate, some unexplored, to satisfy even the most ardent enthusiast. Most scuba divers learn quickly that accurate NOAA charts are an absolute necessity, either to navigate to a specific area or to mark the location of "treasure-found" so it can be relocated on future explorations.

Any fall day near certain Lake Michigan harbors, you can see trailered boats lined up, sometimes for miles, waiting their turn at the launching ramp. The reason for this is COHO! You have to see it to believe it! Since Michigan's Department of Natural Resources decided several years ago to stock certain streams with Coho and Chinook, two varieties of Pacific salmon, the annual spawning runs have gained fantastic interest. With $100,000—plus cruisers and expensive tackle or rubber rafts and bamboo poles, people have flocked to those areas in pursuit of the wily salmon. The fish grow rapidly, are tasty eating, and really give the angler a battle. The salmon generally stay at certain depths, depending on water temperature, before moving upstream. Charter boat skippers and the real students armed with echo sounders, temperature recorders, up-to-date nautical charts, and other aids can almost guarantee limit catches. Last year, one Lake Survey Center employee landed a chinook which weighed 34 pounds and was 44 inches long.

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In winter, Great Lakes marinas are characterized by row on row of snow-covered boats.

Labor Day usually signals the beginning of the end for the boating season on the Lakes. However, many more boaters than in the past seem to be trying to stretch the season for as long as they can. Some feel that fall cruising on the Lakes is best. The waters are less crowded, and nature's annual color show is particularly beautiful from the sea. Experienced boaters know that storms at this time of year can be especially vicious and extra attention to National Weather Service broadcasts is recommended. Most organized activities like races are generally over although a few "frost-bite" cruises and rendezvous are conducted well into November for hardier sailors.

In the fall, the lucky Great Lakes mariner with a large cruiser or houseboat starts to order charts for trips south.

The two main routes to southern waters are to the Gulf of Mexico via the Illinois Waterway (enter at Chicago) and the Mississippi River, and to Florida via the New York State Barge Canal System (enter near Buffalo), Hudson River and Intracoastal Waterway. Either route provides fine cruising and many Great Lakes-area boaters make one or the other regularly.

For others, its the familiar routine of having their boats hauled out, draining fuel tanks, winterizing engines, placing and tying down the bulky protective canvas cover, and throwing away the now obsolete charts after marking next year's calendar with a note to order new ones. In a way it's a sad time; the season is over; but nostalgia will soon be replaced by, "Hey, Dad, can we try Lake Superior next year? Can we, Dad?"

Recreational boating is one of the fastest growing industries in the country. Boating industry experts foresee little slackening of the demand which began just after World War II. In 1950, there were an estimated 3½ million boats in use. The estimate for 1970 was 8.8 million. So, in just 20 years, the pleasure craft fleet has more than doubled.

The Michigan Department of Natural Resource's Waterway Division, in a long-term forecast, has estimated that the state would have over ¾-million boats registered by 1980. Based on recent growth percentages, that estimate may be a little modest.

Among the many factors contributing to the boating boom are lower costs brought about by volume production and the introduction of aluminum and Fiberglas, higher horsepower and more reliable outboard motors, and more money and leisure time available to many Americans. Another factor, although difficult to assess, is the sea's seemingly eternal, magnetic attraction for man.

Whatever the reasons, man's annual springtime migration to the water is an exciting time and a perennial challenge to NOAA whose nautical charts and marine weather service help provide a *bon voyage* to small craft skippers . . . on the Great Lakes and in countless other boating areas across the nation. □

NOAA Profile

Mr. GEODESY

BY RAYMOND WILCOVE

Charles Whitten's career in the National Ocean Survey resulted from his choice between music and science.

A crucial decision four decades ago started Charles A. Whitten in the career that led him to his present post as the National Ocean Survey's Chief Geodesist.

Fresh out of college, he found two avenues open to him, music and science. He chose the latter.

Whitten was impelled to do so because one of his music teachers impressed upon him the fact that musicians have been known to go hungry and, since he was also a top-notch mathematics student, he didn't have to pursue music to make a living. But as an avocation he has maintained his interest in music through the years and has been associated for the past 40 years with his church as a baritone soloist and choir master.

As a scientist he is today an internationally known authority on the crustal movements of the earth as associated with the mechanics of earthquakes. He has made notable contributions in these areas of study which may some day lead to the prediction and even partial control of nature's devastating convulsions. Recently, he proposed that scientists devote more attention to a possible connection between earthquakes and the wobble of the earth on its polar axis and submitted data which appeared to confirm such a relationship.

As he now prepares to leave his post at the end of this month after almost 42 years of service, Whitten, at 62, looks back with considerable satisfaction on a career in government which began during the depression era of the 1930's when, as a member of a geodetic field party, he slept in a tent in both sub-freezing and 100-degree weather, battled mosquitoes in the swamps, and warded off alligators and skunks.

Like many others who work for the Federal government, Whitten had had no intention of getting a job with Uncle Sam. But a professor at Carthage College in Illinois, where Whitten received an A.B. degree in 1930 (and an honorary degree of doctor of science 35 years later) suggested he take a Civil Service exam "just to see what it was like."

He did so well that he received an offer of employment from the Coast and Geodetic Survey, which he accepted. That was 42 years ago and "it's a decision I've never regretted," said Whitten, "even when I was trudging through swamps, carrying an instrument with one hand, and swinging at the mosquitoes with the other."

Whitten spent his first four years in government with the Geodesy Division in Washington and then was detailed for the next two years as chief of an astronomic field party. It was an experience he will never forget. Neither will his wife, Brena, for his bride of less than a year joined him on the four-man party engaged in determining the astronomic latitude, longitude, and azimuth of various sites in the United States.

"So there we were," he recalled, "four men and a girl living out of four tents. Later, one of the other men was married and his wife joined him, so my wife had some company at night when we left

continued

camp to make our astronomical observations. For about the first year, however, she was on her own.

"But we were never so far away from the campsite that I couldn't hear her yell when she needed help, as when an alligator waddled through (he was only a small one) or livestock from a nearby herd poked their noses in."

The Whittens' first child, Bill, was born during this period. "We were in the Mohave Desert," said Whitten, "about 50 miles west of Needles, Calif., when her time came. Our next stop was the Imperial Valley, near the Mexican border."

Enroute to the Imperial Valley, Mrs. Whitten took time off to have her baby in Pasadena, Calif. Then, after a few weeks, she rejoined the party with their son.

"She never had the same doctor twice," recalled Whitten. "But there were no complications. They all said she was leading a healthy life."

Did his wife enjoy the outdoor life? According to Whitten, she did, "just fine, most of the time.

"There were only a few exceptions," he said. "Once was when we had to camp not too far from a plant where they were cooking fish for fertilizer. When the wind blew our way, it was pretty bad. On another occasion, we had to camp alongside the Tamiami Trail in Florida. The traffic, day and night, almost drove us batty.

"We made do with what nature provided," continued Whitten, "we were all young and took it in stride."

They had to be young to endure nature's viscissitudes. At times, the weather grew so cold that the ink would freeze in their pens as the men were transcribing their notes.

The party moved about once a week during the two-year period, always on the go. "I recall one time," Whitten reminisced, "when we were in Georgia. Our chief in Washington, Major William Bowie, said to go to Oregon because the weather there was good. So we packed and drove in our trucks to Oregon only to find, when we got there, that it was raining.

"During that two years, crossing the Rockies—and the roads then weren't what they are today—became a common experience for us. We crisscrossed the Continental Divide back and forth, marking up about 50,000 miles on our trucks.

"It wasn't bad," continued Whitten as his mind spanned the intervening years. "After the first year, we bought a home-made trailer for $225, which I sold at the end of the season for $75." The others in the party continued to use tents.

Before the party broke up in January 1936, they had camped at approximately 100 sites in 40 of the then 48 states, everywhere except New England.

His stint in the field completed, Whitten returned to the comparative ease of the office. Three years later, he was assigned to a triangulation adjustment group and in 1946 was appointed chief of the Triangulation Section. Except for one short period, he remained in the Geodesy Division. That was when Rear Adm. H. Arnold Karo, then Director of the Coast and Geodetic Survey, asked him in 1962 to establish a computer division because of Whitten's experience in this field. Whitten had been active in the conception of computers for geodetic work. In 1948, while he was chief of the Triangulation Section, its first high-speed computers were installed.

"We progressed to the point where we were finally serving the entire agency," said Whitten, "including geodesy, geomagnetism, seismology, cartography, and the personnel division." At this point, the Director instructed Whitten to establish what is now the Electronic Computing Division.

Shortly after World War II, the Survey was asked to assist in the development of plans for the combined adjustment of the triangulation networks of the countries of western Europe. Prior to that time, each country had an independent datum or network. There were major discrepancies and inconsistencies along all borders. Whitten had a major part in planning this international project and then the general responsibility for the computational work of two large blocks of the European network. This unique project provided the opportunity for meeting and for working with the leading geodesists from most of the European countries. This work had been coordinated within the International Association of Geodesy. Whitten became involved in other activities of that association, serving as chairman of commissions, president of the Section of Triangulation, and then finally as its president in 1960.

Whitten has been Chief Geodesist since 1968. Looking back at his work, he regards as most interesting that having to do with crustal movements of the earth, an area in which he has been active for more than a quarter century. His most recent effort in this field, which is closely related to the study of earthquakes, had to do with the polar motion of the earth, or the earth's wobble.

Various scientists since 1906 have espoused the theory that the earth's wobble and earthquake are connected in some manner. Whitten went further. He prepared a graph showing the correlation between the total energy released by recorded earthquakes during the past 70 years and the daily movement of the poles. The graph showed what he considered to be a definite correlation between earthquakes and the polar motion at various periods when the daily shift of the pole reached its maximum, about every seven years. Whitten's study brought new interest to the study of the polar wobble and earthquakes.

Beyond the never-ending task of determining more precisely the size and shape of the earth, Whitten regards one of geodesy's greatest contributions to world knowledge to be the monitoring of crustal deformation in seismic areas, with the possibility it offers that the studies may eventually aid in predicting earthquakes.

But determining *when* earthquakes may occur is to Whitten the least important aspect of the work. "More important than that," he stated, "is being able to establish *where* they may occur and their probable force or magnitude, so proper precautions can be taken in the construction of buildings and other facilities and city planning. Zoning regulations can be established setting up parks or other recreational facilities in the critical areas instead of schools, apartments, and industrial establishments.

"The prediction of earthquakes probably will never become such an exact science," said Whitten, "that seismologists will be able to pick the day or week when one will occur. But man has come a long way in seismic research. Possibly some day man will be able to take steps to mitigate the occurrence of earthquakes. Serious thought is being given to the possibility of avoiding earthquakes by generating a series of minor earth tremors, such as through the injection of water into the earth's crust along a major geologic fault. The technique involved would be to release gradually the strain in the earth's crust and thus avoid a major cataclysm."

Whitten conceded that such research involved a certain amount of risk, for seismologists cannot be certain that attempts to relieve the strain might not in themselves bring on a damaging earthquake.

"These are fairly new concepts," said Whitten, "but people must think in these directions if we are to progress. When you do something to modify the effects of nature, you must take some risks. We don't consider building dams or dikes to control floods a risk, even though they do break at times with disastrous consequences. We consider them safety measures. The day may come, when we've progressed further, when efforts to relieve strain in the earth's crust to avoid earthquakes may be considered an acceptable risk and even a reasonable safety measure."

Another prime interest of Whitten's has been land subsidence and "the very subtle threat" it poses of flooding.

"While many people do not realize it," said Whitten, "the continued subsidence of land in various areas also raises some involved legal questions. In the Houston area, for example, the land has been subsiding some three inches a year. What happens when your land, your industrial establishment, or even your own cellar are flooded

by rising water? What legal recourse do you have? Who are the parties responsible, either for contributing to the cause of the land subsiding or for failing to take corrective actions?"

Whitten believes land subsidence along the east coast, in Texas, Louisiana, and California, to name a few affected areas, may be due to the continued, and increasing, withdrawal of petroleum, water or gas for industrial use. In some areas of California, the land has subsided as much as 30 feet in the past 40 years and some irrigation canals have reversed their flow.

New and evolving theories of the earth's development have also held Whitten's interest for many years. These include what he terms "the time-varying aspects of geodesy," such as continental drift and rotation and sea floor spreading, along with local or regional crustal movements, the polar wobble, "and the interrelation of all these and the problem of understanding earthquakes."

Whitten also has played a prominent role in the program to establish a new North American Datum to replace the one determined in 1927. The North American 1927 Datum has served as a reference for horizontal control and all maps and charts. The new datum, said Whitten, will be a fundamental part of a worldwide geodetic datum now being established through the use of artificial satellites.

Whitten said development of a world datum has important practical considerations. Thus, to cite one example, it is difficult to establish precise international boundaries over submerged continental shelves, where rich oil deposits or minerals may lie, when nations use charts based on different datums.

The development of supersonic planes also requires more precise navigational controls for international flights, especially as the airways become more crowded, and for landing in bad weather, including heavy fog. Where different datums exist, navigational controls cannot be related to each other. Satellite tracking and space exploration depend upon an earth-centered worldwide system.

Still another consideration is the need for more accurate surveying of the oceans, now hampered because oceanographic vessels do not have a common datum with which to work. NOAA ships, while surveying the vast reaches of the North Pacific, using LORAN navigational networks related to Hawaii and the Aleutians, have encountered large discrepancies in positioning.

Whitten said an international agreement is necessary to set up a world datum, and he and other American geodesists have been working with their foreign colleagues for such an agreement at international gatherings. "With the completion of the four-year worldwide triangulation satellite program," said Whitten, "such a datum is now technically feasible."

Whitten regards the opporunity he has had to work with colleagues in many lands as one of his greatest rewards in his many years of service. For the past nine years, he has been a member, the only individual from the Western Hemisphere, of the Finance Committee of the International Union of Geodesy and Geophysics, serving as its Secretary. His work has taken him to numerous professional meetings in the United States, Canada, most of the countries of Europe, Japan, and South America, the most recent in Moscow, at the General Assembly of the International Union of Geodesy and Geophysics, where he represented NOAA and the American Geophysical Union, the latter as its General Secretary.

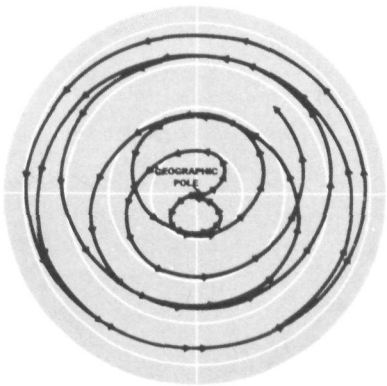
"I have enjoyed tremendously," he said, "pursuing the global aspects of geodesy and geophysics with scientists of other nations. I have been able to demonstrate to my own satisfaction that people can work together, no matter how different their origins and philosophies. Sometimes I am inclined to think that it's more difficult to work with those who speak my own language than with those who do not. In science, the arts, sports—they're demonstrating pretty well that the world is large enough for everyone."

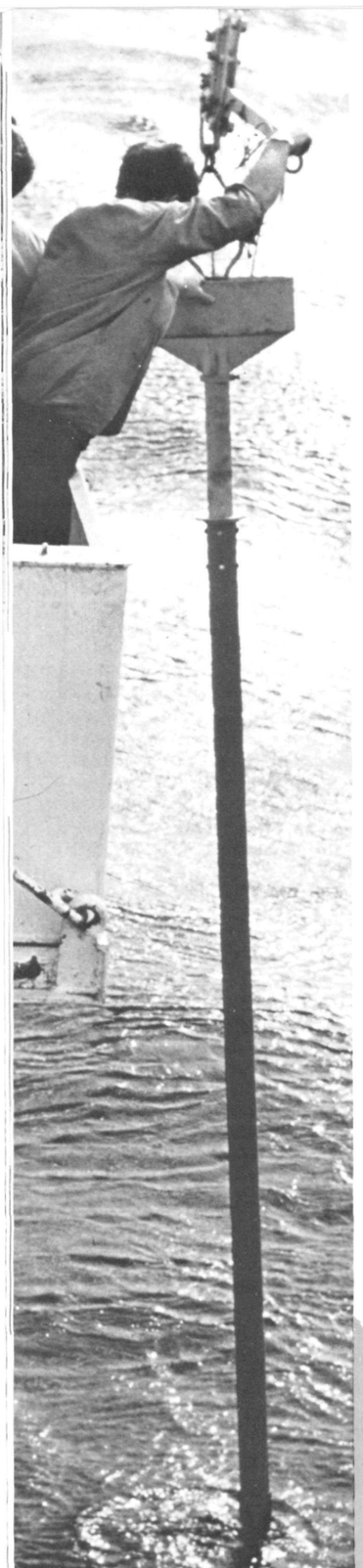
Whitten believes that opportunities for advancement are as good today for young people as they were for him and his associates four decades ago. "Hard work and an impelling interest in your profession are as much the ingredients of success today as they were in the past," he said.

"I always thought that I was given the fullest opportunity to pursue the particular problems in which I was interested," he continued. "As a young man, I admired the professional attitude and respected the capable leadership in the Coast and Geodetic Survey—men like Oscar Adams, Walter Lambert, Clarence Swick, Henry Avers, Howard Rappleye, Hugh Mitchell, C. L. Garner, and Henry Hemple. To the extent that I have been able, I have tried to encourage all those who show interest to pursue their aims within the organization."

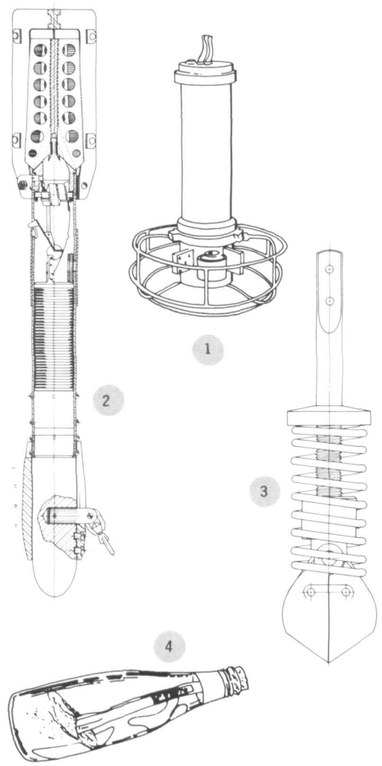
Whitten intends to continue pursuing his aims after he retires. "There are some very important questions for which there are still no answers. I am going to continue trying to find them." □

Recently, Mr. Whitten proposed that scientists devote more attention to a possible connection between earthquakes and the wobble of the earth on its polar axis.

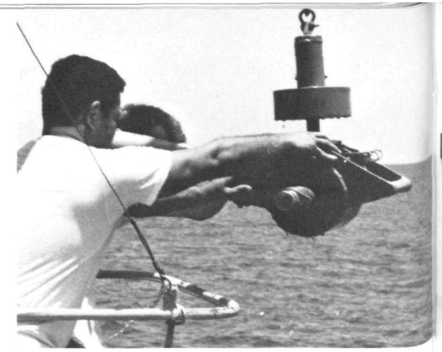




Since man first saw the ocean, he has been developing tools that help to understand it.



(1) The STD draws a trace of temperature as it descends or ascends through the water. (2) Xylene in the tail of the mechanical bathythermograph activates a stylus that etches a gold-plated slide. (3) The clamshell grab traps sediment samples. (4) The familiar beer bottle, ballasted with sand and sealed with a cork, is a tool for tracing ocean currents.



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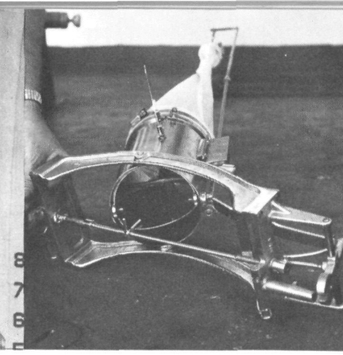

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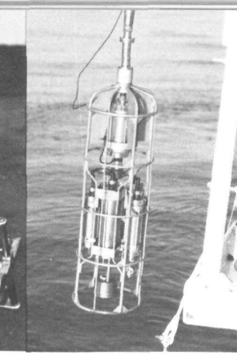

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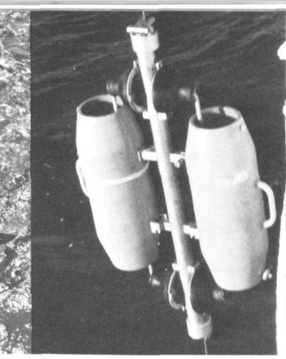

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Many types of instruments may be used to take samples from the oceans and the sea floor. (1) A grab scoops up bottom sediments. (2) A dredge drags up bottom materials. (3) Plankton sampler. (4) Salinity-temperature-depth sampler. (5) To catch tiny floating organisms called plankton, a net similar to a stocking is used. (6) Water sampler.

REACH INTO THE SEA

BY LEON LA PORTE

THE FIRST MAN to appear on our planet must have been curious about his environment.

Then one day a man found the ocean—perhaps the Persian Gulf or the Arabian Sea—and undoubtedly began to explore it with his five senses: he could see the ocean stretching beyond the horizon, he could smell it, he could hear its surf pounding the beach, he could feel its coldness and wetness, and he could taste its salt. This prehistoric man can be considered the world's first oceanographer.

Even early man soon realized that his senses were limited in what they could tell him about his environment. He knew, for instance, that the ocean had depth. But how deep was it? It was deeper than his arm could reach, so he extended his reach by using a stick. Now he could reach the bottom in shallow water, but not in deep water. So he extended his reach still further by tying vines together, weighting them with a rock, and lowering away. As man progressed, his instruments—the extensions of his senses—became more complex, culminating in today's sophisticated array of oceanographic sensors and samplers.

Although surface water samples can be collected with a bucket, water samples from the deep ocean require special sampling bottles. These open bottles are attached to a wire, at intervals determined by the scientist, and are lowered into the ocean. When they reach the desired depth, a weight is sent down the line. The weight trips the first bottle, causing it to turn over. As the bottle turns, it closes, trapping a sample of water. It then releases another weight to trip the next bottle. When all the bottles are closed, they are brought back on deck. The water samples now can be analyzed to determine how much salt or oxygen they contain.

Many types of water-sampling bottles are in use today, but the most popular is the one described above—the Nansen bottle. It was developed at the end of the 19th century by the Norwegian arctic explorer Fridtjof Nansen.

The instrument used for measuring ocean temperatures at great depths is the deep-sea reversing thermometer. This mercury-in-glass thermometer was developed by the Negretti and Zambra Firm of London, England, in 1874. Today, almost 100 years after its invention, this thermometer is still the chief tool used in obtaining precise temperature data from the deep ocean. Its accuracy is within 0.04 degrees.

A series of reversing thermometers can be attached to a string of Nansen bottles, to determine the water temperature at each sampling depth, down to the ocean floor. Down to 900 feet, the temperature can also be measured by a mechanical bathythermograph, a device that draws a continuous temperature graph on a goldplated glass slide carried within. To make continuous temperature recordings to 1,500 feet, another type of bathythermograph can be used. With this instrument, a probe dropped into the water measures the temperature while descending and relays the information through a wire to a recorder aboard ship. Since the probe falls to the bottom and remains there, this instrument is called an expendable bathythermograph.

An instrument of relatively recent vintage, called the STD—for salinity (salt content), temperature, and depth—can continuously measure and record these data to depths of 18,000 feet. This instrument also may be equipped with an audio sender-receiver unit, to measure the velocity of sound through the water.

Empty beer or soft drink bottles can be used to study ocean currents. A bottle cast adrift may be washed up on land, many years later, thousands of miles away. If the scientists know when and where the bottle was launched and recovered, they may be able to reconstruct the path of the currents which carried the bottle ashore. However, these findings may not always be exact.

To catch tiny floating organisms called plankton, a net similar to a nylon stocking is used. By weighing the plankton sample, or by determining how much water it displaces, scientists can determine the amount of food available for fishes and other marine animals (such as whales or clams).

Several types of instruments may be used to take samples of material found at the ocean bottom. One is a grab which scoops up bottom sediments in a manner similar to the way a person grabs a handful of sand. Another is a dredge which drags up bottom material just as a rake picks up leaves. Still another instrument, a corer, takes a tube full of bottom material just like we remove the core from an apple.

The result of man's probing of the sea is oceanographic data—measurements of temperature and salinity, of oxygen available to fish and other sea creatures, of phosphorus and nitrogen available to plants, of silicon available to sponges and plankton, of water acidity, and of the currents that circulate large volumes of water from one part of the ocean to another.

For all these data, there must be a place where they can be centrally processed, then disseminated in their most useful form to all users. Thus, in 1960, the United States established the world's first National Oceanographic Data Center, now a part of NOAA's Environmental Data Service. Since its founding, other countries have established similar data centers.

At the Center, the data are processed by high-speed computers, and geographically sorted so that the user will receive only data pertaining to the part of the ocean he wishes to study. The computer can also draw charts to show where samples were taken, or plots to depict oceanographic parameters—for example, average water temperatures versus depth—in a certain part of the ocean for one or several months.

Data users apply the information in many ways: temperature data are used to determine the location of fishes; salinity data to determine the best areas for oyster farming; nutrient data to determine the availability of material for growth of drug producing plants; current data to design oil rigs and to aid navigation; descriptions of core contents to determine the location and quantity of minerals; water density data to determine underwater sound velocity for SONAR equipment; temperature, salinity, nutrient, current, core, and density data to study changes in the ocean environment due to pollution.

Through the use of instruments and data centers, man has learned much about the ocean. He has applied his knowledge to make better use of the resources and characteristics of the sea. But one enormous task remains—to use this knowledge to determine the ecological balance of the ocean so that some day we may return it to the unspoiled state in which the first curious man found it. □

The oldest existing terrestrial globe was built in 1492 by Martin Behaim and initiated a golden age.

THIS ROUND EARTH

BY PHILIP M. COHEN

AN APOCRYPHAL tale has it that Columbus set forth with four ships on his epic journey, but only three made it to the New World because one fell off the edge.

Only slightly more preposterous was the notion of a pearshaped earth foisted on the public when satellite orbital data in the early sixties revealed a larger mass for the Northern Hemisphere. Lingering effects of this fantasy presumably were dispelled when telecasts from Apollo spacecraft showed a nicely rounded earth.

While man has known for some time that the earth is an ellipsoid of revolution, with some flattening—or oblateness—at the poles, and with deviations from the perfectly spherical for other reasons as well, "round" it most certainly is . . . a round little ball in space.

That we live upon a sphere was first proposed by philosophers of the Ionic School in about 600 B.C. Credit for construction of the first terrestrial globe is given to Crates of Mallos; this was exhibited in Pergamum in 150 B.C.

Aristotle concluded that the earth was round in the fourth century B.C., and one hundred years later Eratosthenes determined its circumference in his classic experiment at Aswan.

The known world existed geographically during the Middle Ages on the knowledge accumulated and presented by Ptolemy on his famous World Map. There was a discernible trend towards acceptance of sphericity during this period, although it may be supposed this was not an easy position to take publicly because of prevailing church opinion. The legacy of the Middle Ages is seemingly modest; yet it includes numerals, the decimal system, eyeglasses, gunpowder, and distillation of alcohol. It also includes the teaching of geography through use of globes.

Philip M. Cohen heads the National Ocean Survey's Marine Geophysics Group.

MARTIN BEHAIM GLOBE

Ptolemy's was, of course, the most famous map of the ancient world, and the first to attempt successfully a spherical representation through use of straight lines for meridians and arcs of circles for parallels. In addition to the cartographic significance of this work, its major land area outlines were accepted for well over 800 years. Few could refute his data and, indeed, there was no basis for doing so. A cursory examination of the map shows India as an island, no Scandinavian Peninsula, the Caspian Sea as perfectly round, and Madagascar more than 1000 miles too far north. A wide river runs east to west in the Sahara. These are major and rather obvious errors to our eyes. Incidentally, a Mercator-like map attributed to the scientist Marinus is said to have existed even before Ptolemy's time, using straight lines for depiction of both meridians and parallels.

Learned men among the Arabs believed in a spherical earth during the Middle Ages, but did so as a corollary to their primary interests in celestial mechanics. They were little concerned with mapmaking as their numerous imperfect cartographic attempts attest. No great cartographic achievements evolved from this source, but as to celestial globe construction an entirely different picture presents itself.

The oldest terrestrial globe extant is the one constructed by Martin Behaim of Nuremberg in 1492. We may recognize this date for another reason; however, there apears to be no connection between the events in question. An immense contribution to cartography, Behaim's work spurred similar endeavors until the use of globes in teaching became commonplace. Today we believe that Behaim was not the careful cartographer he

might have been—that, in fact, he was a poor one. Yet his globe is so significant that this does not detract from its importance. Globes were by no means unknown in 1492, but only two are extant which predate the discovery of the New World. The Behaim Globe is one of these; the other is the Laon Globe, a small sphere used as part of a clock in Portugal, now in Paris.

Behaim was a native of Nuremberg and spent his early years there. He was intended to follow a commercial career and towards this end was sent as a young man to Lisbon and the Low Countries for study and apprenticeship. By far the greatest influence in his life was the seagoing atmosphere in Lisbon. Portugal had by the fifteenth century determined the importance of trade and exploration and was ideally suited geographically and by inclination to be a center of this interest. Behaim made numerous sea voyages from Lisbon and became somewhat of an expert in navigation, although this latter point is disputed by some. It is believed he was knighted at this time. It is known that he visited the Azores and Canaries, and in all probability he sailed down the coast of Africa. So much is credited to him in later German accounts of his life that it is difficult to separate the man from the legend. His known accomplishments are very real, but we also find him rounding the Cape of Good Hope, fighting and winning battles against the Moors at Ceuta, trading shrewdly in India, developing advanced navigational instruments, and coming triumphantly ashore in South America. What little we know of his personal writings only adds more confusion to his deeds.

In August 1491, Behaim returned to Nuremberg with some wealth but with a greater reputation. A member of the Town Council, one George Holzschuher, prevailed upon that body to have Behaim construct a terrestrial globe, incorporating the latest geographic discoveries. This was duly adopted, for which we are grateful for the famous Erdapfel (earth apple).

The globe was constructed in slightly less than a year. It cannot be judged by present standards, but rather may be examined from the standpoint of how well Behaim used available source material. Four chief sources were drawn upon for the globe: the works of Claudius Ptolemy including his geographic descriptions, the writings of Marco Polo, the work of Sir John Mandeville, and accounts of recent Portuguese discoveries.

He followed Ptolemy's ideas closely, more so than was justified in the latter 15th century. The majority of the major land areas are identical on the globe as on Ptolemy's map. It is true that Ptolemaic concepts still ranked highly, but many irregularities known then to occur in Ptolemy were simply duplicated on the globe. Behaim may be faulted for reproducing these data from a source he knew was suspect.

A German account of the travels of Marco Polo was printed in 1477. Polo unfortunately was less a cartographer than he was an adventurer. In his descriptions concerning sizes and shapes of landform, he was grossly in

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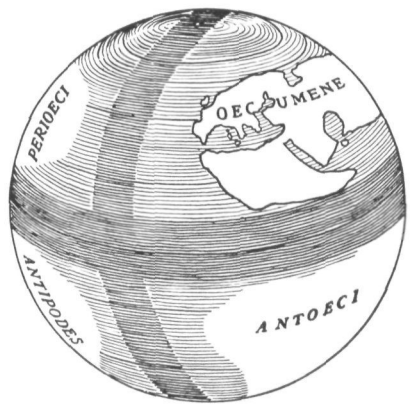
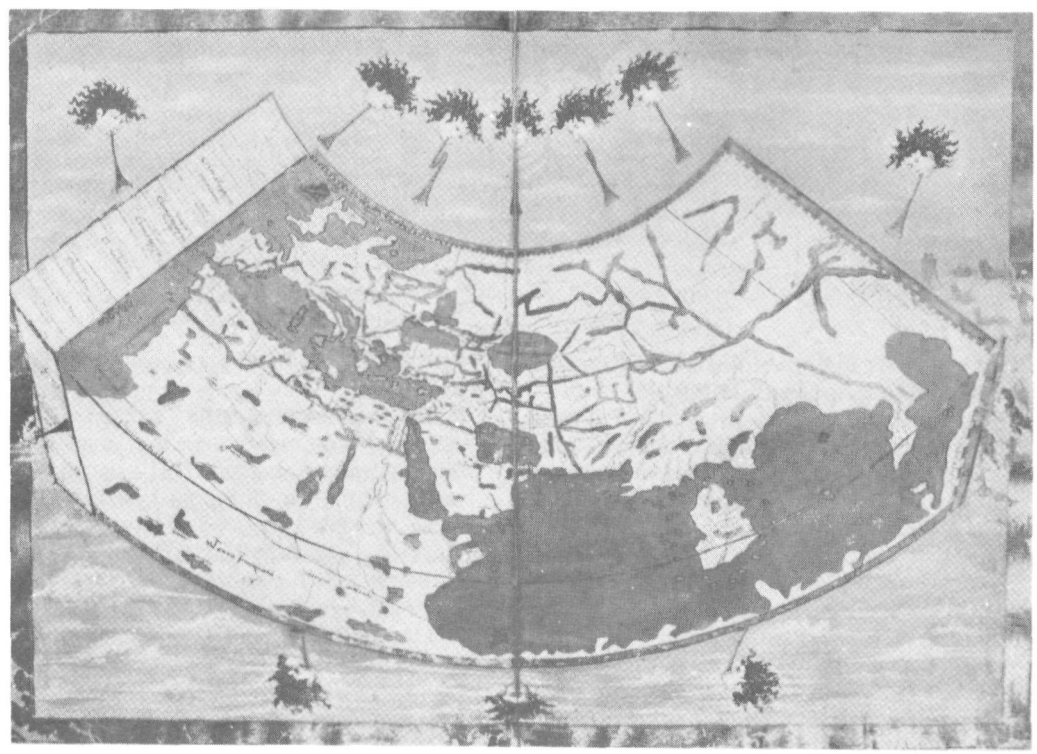


Crates of Mallos is credited with construction of the first terrestrial globe (above), about 150 B.C. Mercator's globe (right) was among those produced by eminent cartographers after Behaim's time.



Ptolemy's world map was the first to attempt successfully a spherical representation through use of straight lines for meridians and arcs of circles for parallels, Ptolemy was one of the chief sources used by Behaim in constructing his globe.

error. There may have been instances where Behaim disagreed with Polo's text, and here it may be that others overruled the use of later but less accepted information. Major disagreement is found between Polo's accounts and more recent portolano charts in the eastern Mediterranean; if Behaim did not use these charts himself, he most certainly was aware of their existence. But in this area on the globe Polo's concepts were shown.

It is not certain to what extent Behaim availed himself of the data presented by Mandeville. Some of Mandeville's ideas seem to have been used, despite the fact that many of them were discredited even in his lifetime.

Of the many sources available to him, Behaim should have found the accounts and particularly the charts of recent Portuguese discoveries the most valuable. Yet almost none of these were used except for data near the Azores.

It is inevitable that examination of Behaim's globe today shows striking errors. The island of Malta is omitted; in Germany, cities such as Hamburg, Cologne, and Frankfurt are not to be found; the Arctic Ocean is completely surrounded by land; and an imaginary island, Antilia, is seen near the Azores. Many errors were due to beliefs of the day; others resulted from poor judgment and editing. The globe must be assessed on these grounds, and it is fortunate for the place that Behaim holds in the history of cartography that his work is transcended by its larger significance.

The globe has a circumference of 1,595 millimeters and a diameter of 507 millimeters. Two great circles are seen, the Equator, divided into 360 degrees, and the Eclyptic. Only one meridian is found, that from pole to pole 80 degrees west of Lisbon. The Tropics, Arctic, and Antarctic circles also appear. Over one hundred miniature drawings are in the empty ocean areas, as are 48 flags and coats of arms. The globe was produced originally in six colors and contains over 1,100 place names.

To his countrymen, Behaim was a giant among men for many years. Real and important as his contributions to cartography and geography were patriotic fervor credited him with even more. From a 17th century memorial address, we find that he was . . . "the prodigy and glory of his age, an incomparable and divine hero, whose accomplishments, though hitherto ignored, redounded to the whole of Germany." And in 1907 at a geographer's convention in Nuremburg, medals were struck with his likeness and a statue of him unveiled. The highlight of one day's festivities was the reading of a poem, "Festspiel Im Hause Martin Behaims," written by Frau Helene von Forster.

At one time, historians speculated on the possibility that Behaim and Columbus met prior to Columbus' first voyage. Indeed, the globe does present the Columbus viewpoint, in that Asia lies further to the east than was generally thought in 1492. It is interesting to dwell on this possible meeting and it cannot be discounted entirely. However, it is doubtful that Columbus would look on the beliefs of the younger Behaim with anything but disdain even if any meetings had taken place. From what we know of Columbus, the theory that Behaim might have influenced him on map sources or geographic theory is implausible.

Behaim's later writings once were thought to have influenced Magellan on the existence of a strait that would lead to India, but here again this was apparently conjecture.

Other notable globes followed, produced by eminent cartographers; Schoner in 1533, de Mongenet, van Langren, and even Mercator all constructed competent globes. It must be remembered that cartographic attempts of all kinds were works of art as well as scientific in nature; portrait painting gained an invaluable backdrop through the ready access of the larger globes. On Mercator's very first globe in 1538, he boldly outlined the New World at the correct distance from the Asian mainland. The original gores from this globe are still preserved at the Royal Library in Brussels.

Behaim initiated the golden age of globe construction and spurred the teaching of a spherical earth. His work stands as a monument in the history of cartography. □

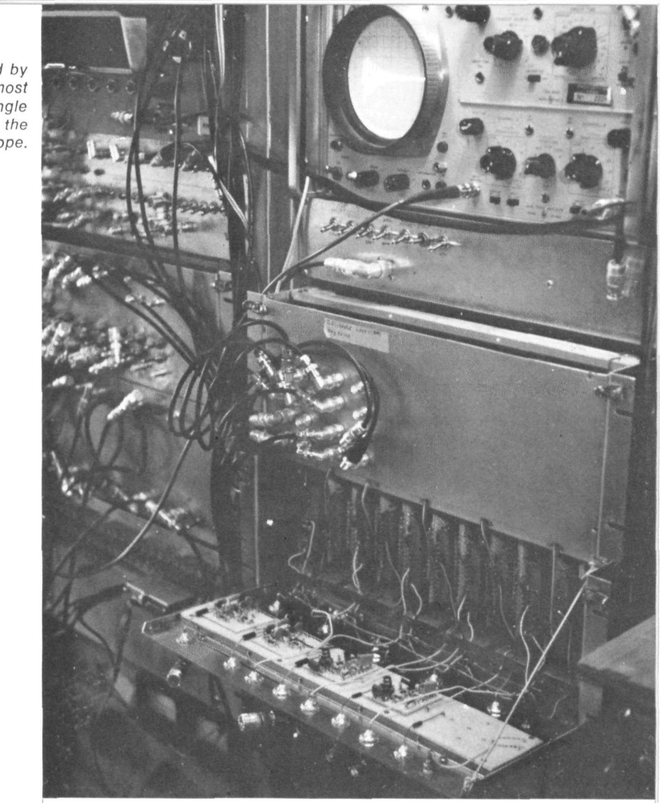
"Orange peel" and polar sections of the Behaim globe show two great circles, the Equator and the Eclyptic.

The Tropic, Arctic, and Antarctic circles also appear. Only one meridian is found, 80 degrees west of Lisbon.

Fingerprinting the Funnel

ERL scientists are using new techniques to detect the special characteristics that distinguish tornadic storms.

BY JOANN TEMPLE DENNETT



The electromagnetic field radiated by lightning increases greatly during most tornadic conditions. (Right) A single lightning response appears on the scope.

One jump ahead of the tornado.

That's the strategy of Environmental Research Laboratories scientists this year, in their efforts to measure the unique characteristics of these storms.

A team from the Wave Propagation Laboratory is following the tornado season from early spring in the gulf states to summer in Illinois and Iowa. Fifteen sites will be equipped to study the electrical nature of tornadic storms, with the network moving northward as the season advances.

At Norman, Oklahoma, home of the National Severe Storms Laboratory, elaborately instrumented vans are positioned in the fields, and a new Doppler radar system awaits the storms that annually boil up over the Oklahoma plains.

Of the Doppler radar system which made its debut last year, Dr. Edwin Kessler, Director of the Norman laboratory, says: "Even though it is still in the developmental stage, we know that there is no substitute for Doppler radar in meteorological studies of precipitating weather systems, especially tornadic storms. The Doppler radar system developed at NSSL tells us what's going on, where, inside a storm. It observes and records the internal storm circulation—and, if there's no circulation, there's not a tornado."

This unique capability was well demonstrated on a single occasion last year when the laboratory's scientists had the opportunity to watch a developing tornado with their Doppler radar. On June 2, 1971, a squall developed in the afternoon over southern Kansas and started moving south-southeastward through central Oklahoma, where it encountered the laboratory's radar and ground data collection network. The Doppler radar system data began to indicate a counter-clockwise circulation associated with an indentation in the radar echo which formed part of a developing hook echo. Pronounced hook echoes—often associated with tornadoes—can also be observed by conventional radar, but the Doppler method provides reliable measurement of the intensity of the associated wind field. In this case, a funnel cloud formed beneath the cyclonic storm vortex 40 minutes after data indicating a vortex aloft were first recorded by the Doppler radar.

NSSL meteorologists Rodger Brown and Kenneth Crawford believe that operational use of Doppler radar should take some of the guesswork out of tornado detection. Studies promise an extremely important and exciting future role for Doppler radar in severe storm research.

Doppler radar's potential to measure otherwise unavailable wind and turbulence data was recognized as long ago as 1960, but the radar's characteristic of producing vast amounts of information actually slowed the development of meteorological Doppler techniques. Processing and handling the data with sufficient speed to be useful is one of the major problems in using Doppler radar operationally. The high-speed data recording and processing schemes developed by Dale Sirmans, electrical engineer, and William C. Bumgarner, systems analyst at NSSL, have made possible the acquisition of Doppler information at the rate needed to deduce accurately the velocity patterns of tornadic storms.

Identification of the tornado-prone zone, long before the birth of the tornado was achieved with only one Doppler radar. The direction and speed of the wind are deduced from the analysis of echoes from windborne particles such as raindrops. By combining the radial velocities obtained with two or three Doppler radars probing the same storm, meteorologists can work out the true velocity and direction of the winds within it.

Increased numbers of Dopplers observing the same storm will take the "assumption and guesswork out of the matter," according to Brown and Crawford. The NSSL scientists expect to have a second 10-centimeter Doppler radar during 1973. A network of three could be used to map completely storm wind fields in three dimensions. Computer programs are now being developed at the laboratory to accept data from such a network. This will give the ability to produce an objective mathematical description of the three-dimensional wind field in a severe storm.

Another possible tool for improved tornado detection is being sought in the joint effort of the National Severe Storms Laboratory and the Wave Propagation Laboratory, to identify an electrical "signature" of a tornado.

A long-standing recognition of the electrical nature of severe storms encouraged remote-sensing specialists at the Wave Propagation Laboratory to mount a field study aimed at identifying electromagnetic signals associated with the birth, growth, life, and death of these most violent of storms, which generate up to 100-million kilowatts of mechanical and electrical power at the height of intensity—one tenth the rate of electric power usage in the United States, all in a whirling column of air a few hundred yards wide.

As meteorologist William L. Taylor explains it: "Many eyewitness accounts of unusual electrical activity in and around tornadoes have been reported during the last 20 to 30 years. In 1950, H. L. Jones gave accounts of lightning and thunder being decidedly different during a tornado than during ordinary thunderstorms—for example, the presence of St. Elmo's fire in the vicinity of a tornado funnel, and the rapid rate of 'one stroke right after another' at the base of a cloud just ahead of a funnel. In 1965 Jones also reported nighttime observations of approximately circular patches of flashing pale blue illumination originating from within severe storms. In 1960 Vonnegut presented a number of references which report brilliant luminous clouds and a ball of fire, and observations of St. Elmo's fire, a buzzing or hissing sound, odors of ozone or nitrogen oxides, and dehydration or burning of vegetation and soil along the path—all indicative of intense electrical discharges near and within the funnel."

During the past two storm seasons, Taylor set up his remote-sensing equipment at the Norman laboratory. These first two years of intensive on-site research enabled the WPL group to conclude that

continued

the electromagnetic field radiated by lightning increases greatly during most tornadic conditions. This electrical activity contains many different frequencies, from a few hertz to many megahertz (a hertz being a cycle per second), but the higher frequency pulses produced during tornadic conditions occurred more often and created a background of almost continuous high rate with few or no individual bursts.

"We could call this enhanced high frequency activity a tornado signature," says Taylor. "It is easily distinguished from the normal non-tornado background activity by its high-frequency spectrum of electromagnetic radiation.

"The energy radiated by the electric current in a tornado-producing storm appears as an almost continuous series of electromagnetic pulses. Each pulse varies greatly in amplitude and contains a wide band of frequencies. The effective range at which we can detect such atmospheric electricity depends on both the pulse amplitude and the frequency we are using."

The data also indicate that tornadoes generally exhibit three stages of electrical activity: first, radio emanation mixed with occasional high-rate bursts produced by discrete lightning discharges; second, enhanced background of almost continuous high rate with little or no isolated burst activity; and finally, slow return to a low-rate background with occasional bursts.

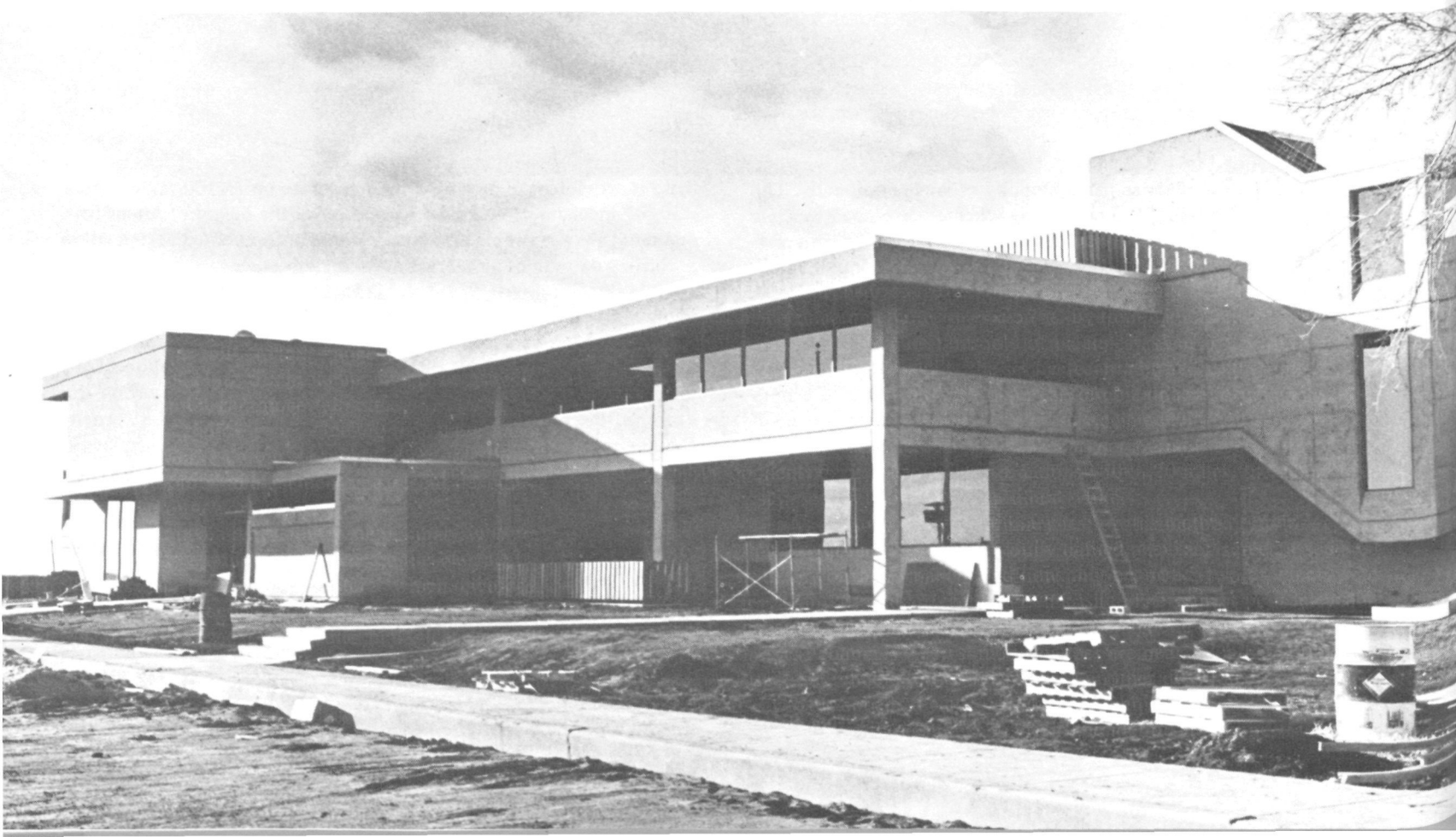
"Based on the present data," Taylor says, "if we are interested in detecting storms within 60 miles, we can probably recognize more than half of the tornadoes by observing enhancement of lightning activity at frequencies of 1 to 10 megahertz. There is a strong chance we could raise the tornado-detection score by observing at 10 to 100 megahertz within a 20-mile radius, but we must wait longer to obtain a statistically significant number of cases in this smaller geographical area before we can be sure."

Concerning the accuracy of a tornado signature in identifying impending tornadoes, Taylor cites data from one April 1970 period. During this time, he says, there were three tornadoes and two tornado funnels within 60 miles of Norman. Using the simplest atmospheric electricity criterion for a tornado signature, he correctly identified four out of five tornadic periods, missing one of the three mature tornadoes.

In the same observational period, eight non-severe thunderstorms occurred within 20 miles. Using the same simple criteria, four of them generated sufficient electrical activity to indicate erroneously that they were severe, and possibly contained tornadoes. The other four produced no electrical enhancement. By applying a more rigid criterion for the identification of severe activity, Taylor says, "we still would have missed the one tornado that showed little electrical activity, but we'd have had a false alarm of a tornado for only one thunderstorm out of the eight non-severe thunderstorms. The fact that we did not get a high-frequency warning from one reported tornado agrees with the whole history of tornado reports and associated lightning, that some tornadic storms are electrical and others are not. We need more research to say why."

Taylor planned his experiment to examine primarily the 10 kilohertz to 137 megahertz frequency band. This wide frequency range allowed him to determine both pulse amplitudes and occurrence rates of virtually all lightning activity associated with tornadoes. An instrumented mobile van measured the rate of arrival of electromagnetic waves at four discrete frequencies, the direction of arrival of the signals, and the earth's potential gradient. A somewhat more elaborately instrumented main van recorded the rate of arrival of electromagnetic waves at 54 megahertz and 137 megahertz, the direction of arrival at three frequencies, and the magnetic field changes; it also was equipped to monitor the brightness of two television sets,

A new building for the National Severe Storms Laboratory is under construction on the North Campus of the University of Oklahoma at Norman. Since 1962, the laboratory has been housed in World War II barracks.



A Doppler radar system awaits the storms that boil up over the Oklahoma plains. Developed at NSSL, it observes and records circulation within the storms.

one tuned to Channel 2 (54 megahertz) and the other tuned to Channel 5 (77 megahertz) or Channel 7 (175 megahertz).

It has been suggested that tornadoes within a 20-mile radius can be detected on a home television set by tuning in Channel 13, darkening the screen to the threshold of blackness, then switching to Channel 2. Thus, technically, the set has been adjusted to the point where electrons will not flow through the circuit under normal household current conditions. The radio waves associated with severe storms and tornadoes can brighten the blackened screen and, according to proponents of this theory, if a tornado is within 20 miles, the whole television screen lights up in a brilliant white.

As a result of his preliminary test of this method, Taylor reports that "we did not experience a fully lighted television screen associated with any of the tornadic conditions that occurred, two of which were less than 20 miles from the antenna site. There must be a television effect of some kind, because the electromagnetic energy does change in these channels when some tornadoes are near. Whether this can be used as a reliable tornado detector is another question.

"It is hoped," he adds, "that new techniques can be devised from the results of these studies to aid in the identification and tracking of tornado activity and severe storms, and to reduce the loss of life and property through improved storm warnings."

This year's experiment will attempt to record the "burst rate" or the frequency of occurrence of groups of electrical impulses. To do this, WPL researchers have instrumented 15 sites in the spring storm belt of Oklahoma, Louisiana, Texas, Mississippi, Illinois, Arkansas, Missouri, and Kansas. The instruments will be moved to new sites further north as the season progresses.

Rather than spreading their observations over a spectrum of frequencies as in past years, Taylor's group concentrated this year's observations at 3 megahertz. Taylor explains: "We believe that observations at 3 megahertz are representative of the electrical energy associated with tornado activity in severe storms. Using relatively simple equipment at this many sites, we expect to see many more storms and hence greatly enhance the statistical meaning of our observations."

Both the Doppler system and the search for an electromagnetic "tornado signature" are in the early stages and require further observations and study to establish their usefulness and reliability for actual operations. Much of this necessary "continued work" is planned for the field studies set in motion every spring at Oklahoma. On the average, at least 61 potentially lethal tornadoes touch this midwestern state every year. Their favorite time seems to be between 3 p.m. and 8 p.m. in April, May, and June, but they can come anytime, posing a danger that continued ERL research may soon diminish. □

THE GREAT MARCH STORM

Warnings of wind-driven waves and tides have been improved by the Weather Service since

The year 1972 marks the 10th anniversary of one of the most unusual storms to strike the U.S. coastline in recent history. It was not a hurricane, but in some ways it was worse than a hurricane.

Beginning on Sunday, March 5, 1962, it lashed the U.S. east coast for five days, from Florida to New England. It killed 33 people, injured 1,252, and caused an estimated 200 million dollars in property damage. Rampaging wind and water destroyed 1,793 dwellings, severely damaged 2,189, and lightly damaged 14,593.

The great winter storm that began March 5, 1962, damaged coastal property from Florida to New England. Devastation at Fire Island, New York (opposite page), and at Cape May, New Jersey (above).

Meteorologists call this type of storm an extratropical storm, to distinguish it from hurricanes, which are tropical in origin and smaller in breadth. Only rarely does an extratropical storm produce this much damage. And only recently has the National Weather Service had the sophisticated forecasting techniques to warn coastal residents of the mighty surges of wind-driven water such a storm will generate.

From now on, when the meteorological ingredients for this type of monster storm are present, forecasters will have a vastly improved procedure for predicting its impact.

How often does such a storm occur? According to Weather Service Director George P. Cressman, "Climatological records indicate that we can expect a storm of this type perhaps once in 20 years, but the risk is always there."

Just how bad it was can be appreciated by a report prepared that year by marine climatologists A. I. Cooperman, of NOAA's Environmental Data Service, and H. E. Rosendal.

Strong, persistent northeast winds raised tides to record or near-record levels, the climatologists said. The fact that the winds were of gale force and at times hurricane force (more than 74 miles an hour) wasn't too unusual for this type of storm, they pointed out, but the persistence of those winds was. In the words of their report:

"The tidal flooding which attended this storm was in many ways more disastrous than that which accompanies hurricanes. The storm surge in tropical cyclones generally recedes rapidly after one or two high tides, but the surge accompanying this storm occurred in many locations, on four and five successive high tides. In addition to this, many places reported run-up of waves 20 to 30 feet high.

"This successive onslaught of wave and tidal action for over two days weakened and undermined even the more-permanent shoreline structures, and after a period of time some suffered structural damage and collapsed. Needless to say, many of the less-sturdy summer cottages on the exposed coast were washed away completely.

"The erosive effect of wave and tidal action changed the face of the immediate coastline, and on many of the well-known beaches the most severe loss was often the sand of the beach itself. In addition, many new channels and inlets were cut in the coastline."

Among detailed effects reported:

—A Liberian tanker split in two 100 miles southeast of Cape Hatteras with the loss of one life.

—Interior portions of Virginia and Maryland received up to three feet of snow accompanied by lightning and thunder.

—The lightship *Chesapeake* was damaged by a 50-foot wave off Hampton Roads and had to leave station.

—The highest winds of the storm—"a peak gust of 84 miles per hour and a sustained wind of 76 miles per hour"—were reported at the Block Island, R.I., airport weather station on the morning of the 6th.

—Ocean waters pushed ashore by the strong winds reached 4 feet above mean sea level along the eastern end of Long Island and 7 feet above in New York harbor. Twenty-foot waves pounded beachfront installations. One hundred houses along Long Island's South Shore were swept into the sea.

—The famed Steel Pier at Atlantic City, N.J., lost a quarter-mile section connecting the auditorium at the end of the pier with the mainland boardwalk.

—Nine persons from two fishing trawlers off the New Jersey Coast were missing and presumed dead.

continued

—Resort towns along the Delaware, Maryland, and Virginia coasts were battered by four or five consecutive high tides accompanied by 20 to 30-foot waves. Boardwalks were reduced to splinters, sandy beaches washed away.

—Up to 1½ million broiler chickens and an unknown number of eggs were lost because of power failures in the poultry-producing Delmarva Peninsula.

—Chincoteague Island, Va., was hit very hard. Extensive damage was done to fishing boats and nets, homes and livestock. A number of the famous Chincoteague ponies were drowned. More than 1,000 persons were airlifted by helicopter to the mainland. The Wallops Island rocket site also suffered heavy damage.

—A fishing pier at Virginia Beach was destroyed. The largest pile driver in the world, worth 1½ million dollars, was turned over on its side in deep water.

—On the elongated islands that make up the Outer Banks of North Carolina, a large proportion of the protective sand dunes along the ocean side were washed flat. A 200-foot-wide inlet was cut across Hatteras Island two miles north of Buxton, and the Hatteras highway was severed or covered up with deep sand at numerous points.

—In Florida, many docks and city streets were damaged or destroyed. Several hotels had lower lobbies flooded. A large British vessel was blown aground about two miles off Port Tampa in the Gulf of Mexico, where related severe weather occurred.

While extensive property damage from a storm of this magnitude is inevitable, no matter how early the warning and how accurate the forecast, human lives and some property now can be saved by new prediction procedures developed since then by the National Weather Service.

The first of these, begun in 1969, is a winter storm reconnaissance program conducted by the Weather Service with the aid of NOAA's Satellite Service, National Data Buoy Center, and Research Flight Facility, and the Air Force, Navy, and Coast Guard.

In this program weather observations are taken in critical portions of the ocean off the east coast by satellites, reconnaissance aircraft, ships at sea and a giant, instrumented buoy anchored 100 miles east of the Virginia-North Carolina border.

Before this program went into effect two and a half years ago, relatively little information was available in the ocean area where some of the most crippling storms are spawned and grow. Still more valuable data will become available later this year when a weather-watching radar is installed aboard the Coast Guard's "Ship H," stationed 200 miles east of Chincoteague, Va.

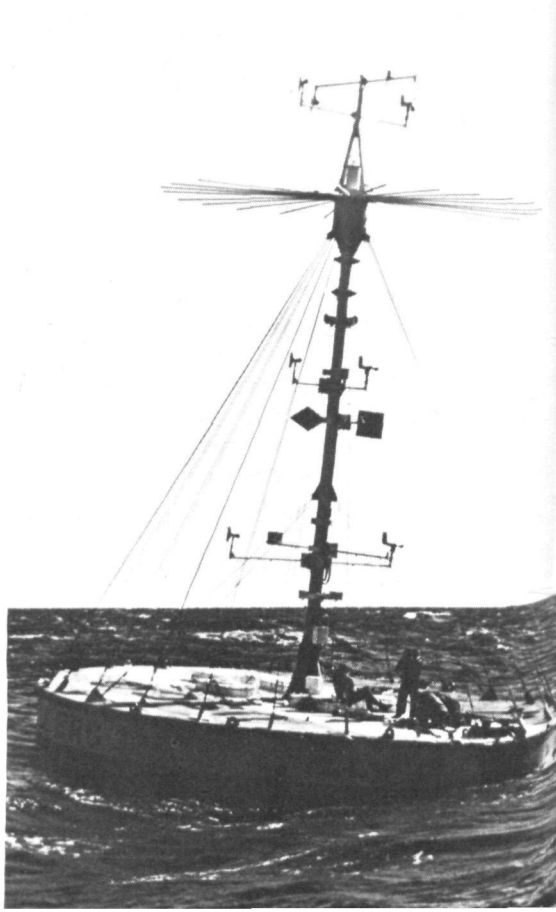
Such observations, taken in the heart of a storm, are processed by computers of the National Meteorological Center at Suitland, Md., and converted into forecasts of storm growth and track so that appropriate warnings can be issued to the populous east coast.

An added refinement in the warning system is a new, computerized system for predicting the height of damaging storm surges which occur on the northeast coast an average of six times each winter season. It was put into effect on an experimental basis this past October. Produced by Arthur Pore and William Richardson of the Weather Service's Techniques Development Laboratory, the computer program is based on equations derived from case histories of 68 storm surges from 1956 to 1969, and used as input data sea-level pressures predicted for numerous grid points off the east coast. From these, wind forces are calculated over the continental shelf, where storm surges are generated. So far, equations have been derived to help predict storm surges at nine locations: Portland, Me.; Boston, Mass.; Newport, R.I.; Stamford, Conn.; New York, N.Y.; Atlantic City, N.J.; Breakwater Harbor, Del.; Baltimore, Md.; and Norfolk, Va.

The result of these two programs should be additional hours of vital warning time, where in years past there was little or none.

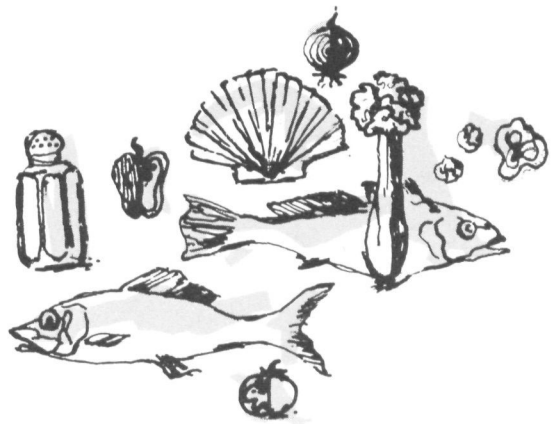
Still unresolved, however, is the problem of overbuilding in vulnerable areas of the coast. Both Weather Service Director Cressman and Dr. Robert H. Simpson, Director of the National Hurricane Center, have spoken out repeatedly against the increasing density of construction in low-lying areas without provision of adequate evacuation plans and without regard for the fact that disasters such as the great Atlantic storm of '62 are bound to recur, sooner or later. They urge planners at all levels of government to press for local building codes which will provide unwary home buyers with greater protection against storms of this magnitude.

"Otherwise," says Dr. Cressman, "nature will impose its own solution." □



(Above) Wave and tidal action weakened and undermined shoreline structures. (Right) A giant, instrumented buoy is part of the system that enables the National Weather Service to provide improved warning of such storms.

A WEALTH OF FISH



It's spring, and the fish are running.

Across the United States, thousands of people are using nets, buckets, and all sorts of utensils to scoop silvery smelt from rivers, lakes, and tributaries. Commercial fishermen are hauling them in by the boatload. In this season, smelt are abundant in the Columbia River, the Great Lakes, and along the east coast from the Gulf of St. Lawrence to the Virginia Capes.

Salmon and shad, too, are springtime delicacies. In late winter and early spring, these fish return from the oceans to their natal streams for spawning. The mechanism that guides them back is a mystery, but it is a boon to fishermen. At this time, they are in prime condition and easily caught.

Shad—members of the herring family—are native to the Atlantic, being most abundant from North Carolina to Connecticut. In the late 1800's, shad were transplanted successfully into the Sacramento and Columbia rivers and now occur along the Pacific coast from the Mexican border to Alaska.

With today's fast, refrigerated transportation, seasonal fish are available fresh in most areas of the country. The National Marketing Services Office of the National Marine Fisheries Service offers some recipes for the plentiful fish of spring.

BAKED SHAD WITH PICKLE STUFFING

1 dressed shad (3 pounds) or other dressed fish, fresh or frozen
Salt
Pepper
Pickle Stuffing
2 tablespoons butter or margarine, melted

Thaw frozen fish. Clean, wash, and dry fish. Sprinkle inside with salt and pepper. Place fish on a well-greased bake and serve platter, 18 by 13 inches. Stuff fish loosely. Brush fish with butter. Bake in moderate oven 350°F., for 45 to 60 minutes or until fish flakes easily when tested with a fork. Makes 6 servings.

PICKLE STUFFING

1 quart dry bread cubes
⅓ cup butter or margarine, melted
¼ cup chopped onion
¼ cup sweet pickle relish
2 tablespoons lemon juice
2 tablespoons chopped parsley
1 teaspoon salt
Dash pepper

Combine all ingredients. Makes approximately 1 quart stuffing.

HEAVENLY SOLE WITH MUSHROOM RICE

2 pounds sole or flounder fillets (approximately 6 fillets, about 6 ounces each), fresh or frozen
½ cup sauterne
½ cup chicken broth
¼ teaspoon tarragon
½ teaspoon seasoned pepper
½ teaspoon salt
¼ teaspoon onion powder
1 can (10 ounces) frozen cream of shrimp soup, thawed
2 tablespoons butter or margarine
3 tablespoons flour

Thaw fillets, if frozen; lightly season with salt and pepper. Roll and secure with skewers or wooden picks. Place in a 1½ quart baking dish. Combine sauterne, broth, seasonings, and soup. Blend butter and flour and add to mixture. Pour over fish. Bake at 375°F., for 15 to 20 minutes or until fish flakes easily when tested with a fork. Serve over Mushroom Rice.

MUSHROOM RICE

1 cup uncooked rice
1 can (2 ounces) sliced mushrooms, drained
½ cup finely chopped green onions, with tops
2 tablespoons butter or margarine
2 cups chicken broth
1 teaspoon salt

Place rice and mushrooms in a 1½ quart buttered casserole. Saute onions in butter or margarine until tender. Add broth and salt; bring to a boil. Pour over rice. Stir well. Cover; bake at 375°F., for 25 minutes or until tender. Fluff lightly with a fork. Makes 6 servings.

SALMON PEPPER STEAKS

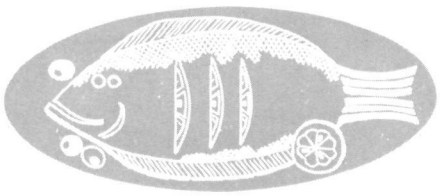
2 pounds salmon steaks or other fish steaks, fresh or frozen
1 cup chopped onion
½ cup chopped celery
½ cup chopped green pepper
3 tablespoons butter or margarine, melted
1 can (1 pound) tomatoes, chopped
½ cup chopped salted peanuts
1½ teaspoons salt
½ teaspoon paprika
⅛ teaspoon crushed red pepper
2 tablespoons flour
¼ cup water
3 cups hot cooked rice

Thaw frozen steaks. Remove skin and bones from steaks. Cook onion, celery, and green pepper in butter until tender in a 10-inch fry pan. Add tomatoes, peanuts, and seasonings. Cover and simmer for 30 minutes, stirring occasionally. Combine the flour and water and stir until smooth. Add to the tomato mixture and cook until thick, stirring constantly. Place fish in sauce. Cover and simmer without stirring for 10 to 15 minutes or until fish flake easily when tested with a fork. Remove the fish from the sauce and arrange over rice. Serve the sauce in a separate dish. Makes 6 servings.

SALMON STEAKS WITH DILLY LEMON SAUCE

2 pounds salmon steaks, fresh or frozen
½ cup butter or margarine
1½ teaspoons salt
2 tablespoons sliced green onion
2 tablespoons flour
1½ cups milk or half and half (half milk, half cream)
1 egg yolk, beaten
2 tablespoons lemon juice
1 teaspoon grated lemon rind
¼ teaspoon dill weed

Thaw frozen steaks. Arrange in well-greased shallow baking pan. Melt ¼ cup butter or margarine; add 1 teaspoon salt; mix. Brush steaks with butter mixture; turn and brush second side. Bake in a moderate oven, 350°F., 20 to 25 minutes or until fish flakes easily when tested with a fork. Save remaining butter or margarine and brush over steaks during baking. While steaks are baking prepare sauce. Melt remaining ¼ cup butter or margarine in saucepan. Add onion; cook slightly. Stir in flour and remaining ½ teaspoon salt. Add milk or half and half and cook, stirring constantly, until sauce is thick and smooth. Add a small amount of the hot sauce to beaten egg yolk. Stir yolk mixture into remaining sauce. Sir in remaining ingredients. Heat to serving temperature. Spoon sauce over salmon steaks. Makes 6 servings.



CRAB-STUFFED HALIBUT

2 pounds halibut steaks or other fish steaks, fresh or frozen
Crab Stuffing
2 tablespoons melted butter or margarine
Lemon wedges

Thaw frozen steaks. Remove skin and bones from steaks. Cut steaks into 6 portions. Cut a pocket in the side of each piece of fish. Divide stuffing into 6 portions, about 2½ tablespoons each. Fill pockets with stuffing. Place stuffed fish in a well-greased baking dish, 13 by 9 by 2 inches. Brush fish with melted butter. Bake in a moderate oven, 350°F., for 20 to 25 minutes or until fish flake easily when tested with a fork. Serve with lemon wedges. Makes 6 servings.

CRAB STUFFING

½ pound crabmeat, fresh, frozen or pasteurized
1 can (6½ or 7½ ounces) crabmeat
1 tablespoon minced celery
1 tablespoon minced onion
1 tablespoon butter or margarine, melted
1 tablespoon minced parsley
1 egg, beaten
2 tablespoons cracker meal
2 teaspoons lemon juice
¼ teaspoon salt
Dash white pepper

Thaw frozen crabmeat. Drain crabmeat. Remove shell or any remaining cartilage. Cook celery and onion in butter until tender. Combine all ingredients. Makes approximately 1 cup stuffing.

CRAB-CUSTARD BALTIMORE

1 pound crabmeat, fresh or frozen
or
3 cans (6½ or 7½ ounces each) crabmeat
2 tablespoons melted butter or margarine
4 slices white bread
1 cup grated cheese
2 tablespoons chopped parsley
1 tablespoon instant minced onion
3 cups milk
4 eggs, well beaten
1½ teaspoons salt
½ teaspoon Worcestershire sauce
¼ teaspoon white pepper
Paprika

Thaw frozen crabmeat. Drain crabmeat. Remove any remaining shell or cartilage. Cut crabmeat into ½-inch pieces. Pour butter in a baking dish, approximately 8 by 8 by 2 inches. Cut crusts from bread. Place bread in a single layer in the bottom of the baking dish. Place crabmeat over top of the bread. Sprinkle cheese, parsley, and onion over crabmeat. Combine milk, eggs, salt, Worcestershire sauce, and pepper; pour over crabmeat. Sprinkle with paprika. Set baking dish in a pan containing 1-inch of hot water. Bake in a moderate oven, 350°F., for 45 to 60 minutes or until knife inserted in the center comes out clean. Makes 4 to 6 servings.

CATFISH CANTONESE

3 pounds pan-dressed skinned catfish, or other fish, fresh or frozen
¼ cup melted butter or margarine
¼ cup lemon juice
1½ teaspoons salt
¾ teaspoon paprika
Dash pepper
Sweet-Sour Sauce
Julienne cut strips of fresh carrots, celery, and green pepper

Thaw frozen fish. Remove fins and tails. Clean, wash, and dry fish. Place fish in a single layer on a well-greased baking pan, 15x10x1 inches. Combine remaining ingredients except Sweet-Sour Sauce and vegetables. Brush fish inside and out with sauce. Broil about 6 inches from source of heat for 8 to 10 minutes. Turn carefully and baste with remaining sauce. Broil 8 to 10 minutes longer or until fish flake easily when tested with a fork. Place fish on a warm serving platter. Pour hot Sweet-Sour Sauce over fish. Garnish with vegetables. Makes 6 servings.

SWEET-SOUR SAUCE

½ cup water
3 tablespoons catsup
3 tablespoons soy sauce
3 tablespoons sugar
1½ tablespoons vinegar
2 tablespoons cold water
1 tablespoon cornstarch

Combine water, catsup, soy sauce, sugar, and vinegar in a 1-quart sauce pan. Heat. Combine water and cornstarch. Add to sauce and cook until thick and smooth, stirring constantly. Makes approximately 1 cup sauce.

CHEESY OVEN-FRIED SMELT

3 pounds pan-dressed smelt or other small pan-dressed fish, fresh or frozen
½ cup milk
½ teaspoon salt
1½ cups flavored dry bread crumbs
¼ cup grated Parmesan cheese
⅓ cup butter or margarine, melted
Paprika

Thaw frozen fish. Clean, wash, and dry fish. Combine milk and salt. Combine crumbs and cheese. Dip fish in milk and roll in crumbs. Place in a single layer in well-greased baking pans 15 by 10 by 1 inches. Pour butter over fish. Sprinkle with paprika. Bake in an extremely hot oven, 500°F., for 8 to 10 minutes or until fish flake easily when tested with a fork.

BAKED PICKLED MACKEREL

3 pounds pan-dressed mackerel or other pan-dressed fish, fresh or frozen
Salt
Pepper
1 cup thinly sliced onion
1½ cups vinegar
1 tablespoon mixed pickling spices
2 tablespoons butter or margarine

Thaw frozen fish. Clean, wash, and dry fish. Sprinkle inside with salt and pepper. Place fish in a single layer in a well-greased baking pan, 15 by 10 by 1 inches. Stuff fish with onion. Combine vinegar and spices. Pour over fish. Dot fish with butter. Bake in a moderate oven, 350°F., for 25 to 30 minutes or until fish flake easily when tested with a fork.

President Names Peter G. Peterson To Head Department of Commerce

Peter G. Peterson's nomination to the post of Secretary of Commerce was confirmed by the Senate February 21.

Formerly Assistant to the President for International Economic Affairs, Mr. Peterson had been a member of the White House staff since February 1971. He had served previously in executive posts with Bell and Howell—as Chairman of the Board and Chief Executive Officer from 1968-71, as President from 1961-68, and as Executive Vice President and Director from 1958-61. He also was Director of IMC Magnetics Corporation.

Before joining Bell and Howell, Mr. Peterson had been with Market Facts, Inc., becoming Assistant to the President in 1957.

A native of Kearney, Nebraska, he attended the Massachusetts Institute of Technology and received his bachelor's degree from Northwestern University in 1947. He also holds a master's degree in business administration from the University of Chicago.

In 1955, the Chicago Junior Chamber of Commerce named him the city's Outstanding Young Man.

Mr. Peterson and his wife, the former Sally Hornbogen, have three sons—John Scott, James Stuart, and David Barnes.

Advanced Computer Ordered for GFDL

An environmental computer system, ten times more powerful than any computer system now commercially available, is being built for the Geophysical Fluid Dynamics Laboratory to provide its scientists a new and improved tool for studying the behavior of the world's weather and oceans.

With the new system, it will be possible to simulate the circulation of the air and the sea, and the interactions between them, more accurately than ever before.

On behalf of NOAA, the General Services Administration awarded a contract to Texas Instrument, Inc., for the system known as the Advanced Scientific Computer. The contract provides for an eight-year lease, beginning at about 4½ million dollars per year and decreasing thereafter, with an option to buy.

The new machine is expected to be installed by mid-June 1973, at the laboratory on the Forrestal Campus at Princeton University.

Since 1955 the laboratory—headed by Dr. Joseph Smagorinsky—has been developing numerical models that simulate the physical processes taking place in the earth's fluid envelope—the oceans and atmosphere.

According to Dr. Smagorinsky, "The new computer will permit us to accelerate research in the modeling of the combined atmospheric/oceanic system in support of the objectives of the World Meteorological Organization's Global Atmospheric Research Program. The enhanced simulation capability will still mainly be limited by computing power, but will demand fewer simplifying compromises in design. It will therefore provide a better understanding of the physical factors that significantly influence the global system."

W. W. Behrens, Navy Admiral, Appointed to New NOAA Post

Vice Admiral William W. Behrens, Jr., USN, has been appointed Associate Administrator of NOAA for Interagency Relations.

Admiral Behrens, who had been Oceanographer of the Navy since September 1970, remains an active duty officer in the Navy and also serves as the NOAA Administrator's Naval Deputy, providing direct liaison and coordination between NOAA and the Navy on oceanographic and similar affairs. His office is the focus for

tional programs with other agencies in marine and undersea science, technology, and services.

During his Navy career, Admiral Behrens has served in a number of positions with responsibilities related to the Navy's interests in the environmental sciences and with a background in sonar development work. He was the first to install electrical slip rings for the Navy's trainable sonar in 1944, was later project officer for the underwater telephone used in ship-to-ship communications, and also was underway project officer for the Navy's first scanning sonar equipment. For two years, in 1950-52, he was an instructor in the Navy's Fleet Sonar School. As Oceanographer, Admiral Behrens directed the entire oceanographic effort of the U.S. Navy.

He was graduated from the U.S. Naval Academy and commissioned an ensign on June 9, 1943. When selected for Rear Admiral in 1967, he was the youngest officer the Navy had ever promoted to Flag rank. Admiral Behrens has advanced education in nuclear engineering, was the first Director of the Navy's Nuclear Power School, and holds the degree of master of arts in international affairs from the George Washington University. He has also served in the Atomic Energy Commission and the Department of State.

Year-Long International Study of Lake Ontario To Provide Basis for Improved Lake Management

NOAA is the lead U.S. agency for a concentrated year-long study of Lake Ontario by about 600 Canadian and U.S. scientists and technicians scheduled to begin on April 1.

The purpose of the study, known as IFYGL—the International Field Year for the Great Lakes—is to improve the scientific basis for management of Great Lakes water resources.

Dr. Eugene Aubert of NOAA is Director of the IFYGL Project Office, and operational headquarters for the U.S. are at Rochester, N.Y. Initial development of the scientific program and continuing policy guidance came from a U.S. Steering Committee chaired by W. J. Drescher, U.S. Geological Survey. Overall scientific policy guidance has been provided by the Canadian and U.S. National Committees for the International Hydrological Decade (I.H.D.), working through their respective IFYGL Steering Committees.

During the study, universities and government agencies from both nations will use a network of towers and buoys in the lakes, ships, aircraft, weather stations, and satellite data to gather information about the 30,000 square-mile drainage basin of Lake Ontario.

Approximately equal resources are being deployed from both countries, and the total allocations by the two nations for the period 1971-1975 are estimated at $15,000,000. The current IFYGL schedule calls for the intensive data collection program through 1972; completion of field work, data reduction, and initial analyses in 1973; and further analysis assessment, and publication in 1974 and 1975.

The task of the IFYGL scientists will be:

—To report the condition of the lake, specifically the hydrological, chemical, and biological features;

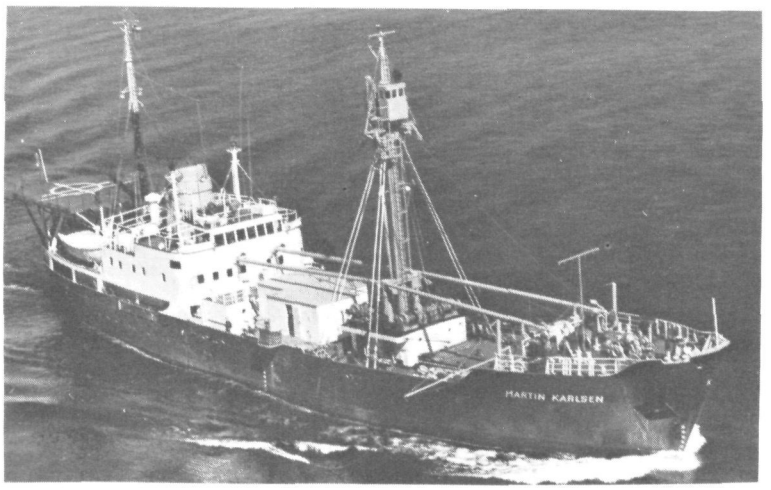
—To describe the lake's processes, and the interrelationships among the hydrological, chemical, and biological elements.

—To create computer models that will enable scientists and others to predict the effects of proposed changes in lake uses or lake environment.

Major problems of lake management that will benefit from the study are pollution control; control of lake levels, which affect hydroelectric power, navigation, and shore erosion; and improved weather forecasts and mathematical modeling of lake- or ocean-atmosphere interaction.

There will be five major data gathering systems:

—Major research vessels to be provided by each nation will make detailed measurements of meteorology and subsurface water characteristics, and will obtain water samples for biological and chemical data. Data on ship position and time will permit information users to know exactly where and when each sample was taken. (NOAA will provide the RESEARCHER from the National Ocean Survey and the ADVANCE II by lease from Cape Fear (N.C.) Technical Institute.



The research vessel MARTIN KARLSEN, operated by the Canada Centre for Inland Waters, is one of the three major Canadian ships participating in the International Field Year for the Great Lakes.

—Specially instrumented buoys (11 Canadian and 10 U.S.) and towers will provide time series data in the lake on air and water temperature, humidity, air pressure, wind speed and direction, precipitation, radiation, and currents.

—Weather radars at Toronto (Canada), Buffalo (N.Y.), and Oswego (N.Y.) will provide precipitation monitoring.

—Rawinsonde stations (Scarborough, Presqu' Ile, and near Hamilton, Canada, and at Stony Point, Sodus Point, and Lakeside Beach State Park, N.Y.) with advanced wind sounding instrumentation will make possible not only the standard pressure and temperature measurements for upper air soundings, but, through a tie-in with a LORAN C navigational system, more precise tracking of the balloons, thus providing very exact wind speed and direction measurements.

—Aircraft provided by Canada and the United States (through NOAA's Research Flight Facility and the National Center for Atmospheric Research) will be used for boundary layer measurements. Other aircraft will utilize remote sensing to obtain surface temperature, snowpack, and ground moisture information not previously available.

Supplementing the five major data gathering systems will be hundreds of temperature, river, and rain and snowfall measuring stations that dot the basin on both sides of the international boundary. Stream gaging stations on all major streams and rivers monitor the water flow. Water levels in wells will be checked periodically, and soil moisture studies will be undertaken periodically to find rates of water infiltration and evaporation.

NOIC Regional Center Planned

NOAA's first regional National Oceanographic Instrumentation Center will be established at the NASA Mississippi Test Facility in Bay St. Louis, Miss., as the result of a recent agreement between NOAA and NASA.

The new regional center will be responsible for providing instrumentation test, evaluation, calibration and services to the National Data Buoy Center. The services also will be available to other federal and state agencies, on a reimbursable basis, and to universities and private enterprises. NOIC's headquarters are in Washington, D.C.

Because of this intensive test and performance evaluation program, ocean-going instruments such as conductivity, temperature and depth systems, current meters, salinometers and marine meteorological instrumentation systems will be able to furnish more accurate and reliable readings of salt content, depth, and temperature of our world's waters. Plans also call for future testing and calibration of related environmental instruments and equipment.

NMFS Awards Grants to Two States For Rehabilitation of Oyster Reefs

Resource disaster grants—$200,000 to the State of Florida and $70,000 to the State of Alabama—have been approved by the National Marine Fisheries Service for oyster rehabilitation projects.

The funds are made available as a resource disaster grant under provisions of the Commercial Fisheries Research and Development Act of 1964, administered by the NMFS. Fishery resource disasters arising from natural or undetermined causes are eligible for funding under the Act.

The State of Florida will establish new, permanent and productive oyster reefs in the two northwest Florida counties where traditional oyster reefs were destroyed by a natural disaster. The work will be done in selected bay and estuary areas of Escambia and Santa Rosa Counties.

Samples of oysters taken during the first few days of the Florida open oyster season (starting September 1971) showed that between 70 and 99 percent of all oysters along the east bank of Escambia Bay perished from an oyster-parasatic-fungus disease. The area of the kill constituted more than 60 percent of the total natural approved acreage used prior to the 1971-1972 season, and constituted more than 110 acres of oyster reefs. The total loss was about 38,000 bushels of harvestable oysters valued at about $300,000 at retail.

In Alabama, approximately 95 percent of an oyster resource on Pt. Clear Reef, Mobile Bay, was killed by insufficient oxygen in August 1971. Eight oyster processors, 53 retail outlets, and approximately 129 oystermen had been partially or totally dependent upon the 195-acre oyster reef. In addition, this reef had furnished seed oysters for approximately 500 acres of leased State oyster grounds. The disaster represented an economic loss of some $95,508 to the fishermen, and a loss of approximately $200,000 to the area's economy.

Since similar oxygen shortages have occurred in the vicinity for at least the last century, a 195-acre portion of Whitehouse Reef, also in Mobile Bay, but not historically subjected to such shortages, will be converted to an oyster reef to replace the lost resource.

Porpoise Deaths Reduced by Modified Tuna Seine

A new technique for reducing the number of porpoises trapped in large tuna nets has lowered porpoise mortality by 75 percent in tests conducted by the National Marine Fisheries Service and the U.S. Navy.

A net modification that permits the escape of trapped porpoises was tested in a month-long study aboard a chartered commercial tuna vessel.

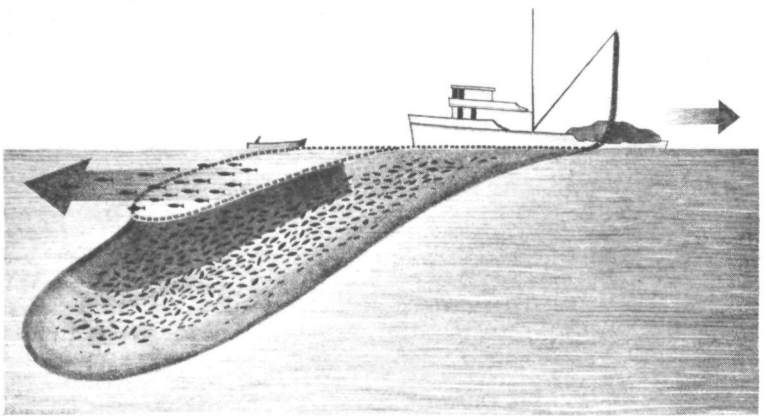
Schools of yellowfin tuna are the mainstay of the U.S. fishing fleet based at San Diego, California. Yellowfin tuna make up about half the total tuna catch by U.S. fishermen, and more than 90 percent of the yellowfin is now caught by large nets, called purse seines. The tuna frequently swim beneath schools of porpoise which are visible at the surface in tropical waters. Fishermen use this knowledge to set their nets for catching tuna. In the process, they may capture part of the porpoise school, and some porpoises become entangled deep in the net before they can be released. Being mammals, the porpoises suffocate without air. Porpoise mortality has been a matter of increasing concern.

The purse seine modification, developed by Harold Medina, a well-known tuna boat captain, involves insertion of a strip of smaller mesh netting in the back end of the large net. This smaller mesh prevents porpoise snouts and flippers from being tangled in the net and increases the effectiveness of an established procedure of porpoise release, called "backing down." In backing down, the fishing vessel maneuvers in such a way that the float line at the back end of the net sinks beneath the water surface, allowing the porpoise to swim out over the top of the net.

In 25 sets conducted during the recent study, the modified net reduced average porpoise mortality by 75 percent, as compared to earlier observations with unmodified purse seines.

While the tests were encouraging, additional data must be accumulated from tuna boats on a catch-by-catch basis. Tests will continue with the cooperation of the Navy and the tuna fishermen with the aim of entirely eliminating porpoise mortality.

The tests involved personnel from the NMFS laboratory at La Jolla, Calif., and the Naval Undersea Research and Development Center, San Diego. William E. Evans, Senior Research Zoologist at the naval installation directed the research, planned with NMFS Project Leader William Perrin. The American Tuna Boat Association made the arrangements for the seiner QUEEN MARY, captained by Joseph Medina to take part in the tests.



Fishing vessel maneuvering so that the float line at the back end of the net sinks beneath the water surface, allowing the porpoise to swim out over the top of the net.

Seismic, Estuarine Studies Initiated in Puget Sound Area

The Puget Sound area is the subject of two important studies recently begun by NOAA. One project is gathering data on the circulation of the Sound; in the other, the region's earthquake risk is being examined in detail.

A network of instruments is now being installed by ERL's Earth Sciences Laboratories in the Puget Sound area, in preparation for a study of the region's response to earthquakes.

The study is the first for a large metropolitan area with regional geology and soils distribution as an integral feature, and is the forerunner of similar programs in other U.S. cities of high seismic risk.

The Puget Sound network, when completed, will consist of about 30 accelerographs installed in a geologically influenced pattern, and about 60 seismoscopes in the Seattle-Tacoma metropolitan area. At present, 10 accelerographs and 5 seismoscopes are in place there.

Data gathered by the devices will be applied to the development of detailed seismic risk maps and improved earthquake building codes for this region which includes the densely populated Seattle-Tacoma metropolitan area.

A series of important surveys in Puget Sound has been initiated by the Pacific Oceanographic Laboratories and the NOAA Ship MCARTHUR.

The surveys will study various aspects of Puget Sound's circulation, averaged over several tidal cycles, and how the circulation alters with changes in such factors as tide and tidal currents, water properties, river runoff, seasonal changes in water properties outside the estuary, and winds.

The knowledge sought is considered basic information for rational management in the estuary of the ever-increasing and multiple demands placed on it, including pollution abatement and control, biological studies, and the design of estuarine monitoring networks.

The surveys will be made in the central basin of Puget Sound, with the cooperation of the University of Washington. Initial surveys were carried out from January 31 to February 11 and February 28 to March 3, and plans are to continue them next winter and summer.

Sea Grant Study Breeds Mullet In Laboratory

Controlled reproduction of mullet—including out of season spawning—has been achieved by scientists of the Oceanic Institute, Waimanalo, Hawaii.

These dramatic research results, achieved under a NOAA Sea Grant, bring into the foreseeable future commercial breeding and farming of this widely used oceanic food fish.

While not eaten in many parts of the United States, mullet is a major food fish in large areas of the world.

Dr. Ziad H. Shehadeh and his colleagues at the Oceanic Institute have succeeded in spawning the fish in September, five months earlier than the natural mullet spawning season of January and February.

After four years of research and experimentation, the Oceanic Institute scientists began to solve the problems of controlled spawning, fertilization, and rearing. Their first success came about one year ago, in December, 1970, when they achieved a successful mullet spawning in the laboratory. Later this was duplicated by another scientific team working with the Oceanic Institute group in Taiwan.

Kohler Named To Top NWS Hydrology Post

Max A. Kohler has been named Associate Director for Hydrology of the National Weather Service. As head of the river and flood forecasting program, he succeeds William E. Hiatt, who retired in January.

Born in Lincolnville, Kansas, Mr. Kohler received a bachelor of science degree in physics from the University of New Mexico in 1939. He began his career with the Weather Service (then Weather Bureau) at Roswell, New Mexico, in 1940. He has worked in hydrology at Weather Service headquarters since 1942. In August 1953, he was named chief research hydrologist. Early in 1965, he became Chief Hydrologist and, since 1969, has also been serving as Director of the Research and Development Laboratory in the Office of Hydrology.

Mr. Kohler served as President of the World Meteorological Organization's Commission for Hydrometeorology from 1961-68, and was President of the American Geophysical Union's Section of Hydrology from 1968-70. He is now Chairman-Elect of the American Association for the Advancement of Science's Section on Atmospheric and Hydrospheric Sciences, and a member of the Council of the American Meteorological Society.

He received a Department of Commerce Silver Medal in 1949 and the Gold Medal in 1959.

Graphics Radioed From Ship to Shore

Graphic material has been transmitted successfully by ship-to-shore radio, from the NOAA Ship MT MITCHELL at her base in Norfolk, Va., to National Ocean Survey headquarters in Rockville, Md.

The first graphic material transmitted from the ship was a three-by-three-inch emblem of the NOAA organization. The transmission took about two and a half minutes.

Captain Dewey Rushford, Chief of the National Ocean Survey's Ship Facilities Division, which conducted the experiment, said the transmission of graphics "provides another important link in ship-to-shore communications.

"It will lend itself to almost unlimited uses, once it is perfected," said Rushford. "To cite a few examples, photos of schools of fish can be transmitted to shore stations and oil slicks and other pollution at sea can be reported visually, along with information on wrecks and other dangerous navigational hazards and hydrographic data."

Two Seamounts Rising, Pacific Study Reveals

Two well-known seamounts—Cobb and Bear—may eventually rise above the sea surface and become islands, National Ocean Survey scientists reported after a five-month survey of the sea bottom by American, Canadian, and Japanese scientists aboard the NOAA Ship SURVEYOR.

The survey also revealed the existence of sediment deposits off the coasts of Washington and Oregon that suggest the presence of oil.

Data gathered during the expedition completed in November are now being analyzed by a team of scientists from the National Ocean Survey in cooperation with two Canadian and three Japanese geophysicists who participated in the expedition.

While a complete analysis of the data will take months, new light has already been shed on the topography of the Pacific Ocean's sea bottom in the 850-by-360 mile area west of Washington and Oregon covered by the expedition.

Analysis of the data has determined the southern boundary of a submerged plain at least as large and perhaps larger than the central United States, covered with sediment through which deep sea channels meander in a fashion more complex than the Mississippi-Missouri River watershed. One channel was estimated to be 600 feet deep and six miles wide. The plain lies an estimated 60 to 600 miles off the coasts of British Columbia, Washington, Oregon, and California approximately 2½ miles below the surface of the ocean.

The data revealed that the topography of the flat area, known as Tufts Plain, is considerably more complex than previous investigations had shown it to be. The full extent of the plain must still be determined. Although its southern boundary has now been delineated, its western and northern boundaries are still unknown.

The data revealed that the 300,000-square-mile area studied by the expedition—comparable in size to that portion of the U.S. extending from the Washington-Oregon coast to the Black Hills on the Wyoming-South Dakota border—is flat, except for two areas of undersea mountains about 50 to 300 miles off the coasts of California, Oregon, Washington, and British Columbia. The mountainous areas are the Juan de Fuca and Gorda rises, topped by the Cobb and Bear seamounts.

NOAA geophysicist Douglas J. Elvers, the project's chief scientist, said the study disclosed that the submerged mountainous areas are "in a definite stage of uplift similar to the western coast of Canada and southern Alaska." The new data suggest, added Elvers, that the two principal undersea mountains—Cobb and Bear—may eventually rise above the sea as new islands, "either through volcanic growth or general uplift of the rises." Cobb Seamount, whose top has been explored by various expeditions, lies only 110 feet below the surface, about 340 miles southwest of Seattle, Washington. Bear Seamount is just south of Cobb. It was estimated that the mountainous areas extend for about 600 miles from Northern California to the northern tip of Vancouver Island, British Columbia.

The data analysis also revealed the existence of a trench filled with sediment, mainly sand and silt, more than a mile thick. The trench lies at the base of the continental slope off the coasts of Washington and Oregon, more than 1½ miles below the surface of the sea. Elvers said "major folded sediment deposits near the coast will be of interest to oil prospectors."

Mississippi River Forecast Center Opened by NWS

The National Weather Service officially commissioned its Lower Mississippi River Forecast Center at Slidell, La., in January. The new center, authorized by Congress and physically located in the National Aeronautics and Space Administration's Slidell Computer Complex, has been established to provide daily forecasts of river states and flow on the Mississippi River and its tributaries between Cairo, Ill., and the Gulf of Mexico, and for other principal rivers in the South-Central States.

The center serves a total watershed area of some 200,000 square miles comprising portions of Louisiana, Mississippi, Tennessee, Arkansas, and Missouri. It receives rainfall reports from some 450 reporting points and has information from 125 river gaging stations available to it on a daily basis.

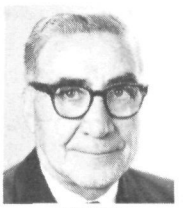
The NWS is responsible for forecasting the river stages of the Nation and to warn of floods, and has developed sophisticated mathematical techniques for such forecasting. The needed computer support for these daily computations is being supplied by the Slidell Computer Complex, which already has a highly advanced computer capability acquired to support the National space program at the NASA Mississippi Test Facility, Bay St. Louis, Miss., and the Michoud Assembly Facility, New Orleans, La.

Dr. George P. Cressman, Director of the NWS, the principal speaker at the dedication ceremonies, referred to the economic importance of the River Forecast Center, and pointed out that the highly accurate forecasts of water levels are needed for protection of life and property during flood threats, and that because of increasing need for careful management of the Nation's total water resources, forecasts of normal and low-flow conditions are also important to the use of rivers for navigation, water supply, waste disposal and the recycling of water.

Admiral Jones To Retire; Powell Will Head NOS

Rear Admiral Allen L. Powell, Director of National Ocean Survey Fleet Operations, has been nominated by President Nixon to succeed Rear Admiral Don A. Jones as NOS Director. Admiral Jones will retire on April 30.

Captain Eugene A. Taylor, Deputy Associate Director for Fleet Operations, will become Director of Fleet Operations and will be promoted to the rank of Rear Admiral, lower half.



ADMIRAL DON A. JONES

REAR ADMIRAL ALLEN L. POWELL

Admiral Jones' retirement ends a 39-year career with the National Ocean Survey and its predecessor, the Coast and Geodetic Survey.

Admiral Jones was born in 1912 at Waldron, Michigan. He earned his bachelor's degree in civil engineering from Michigan State University in 1933, and is also a graduate of the U.S. Armed Forces Staff College at Norfolk, Virginia.

He joined the Coast and Geodetic Survey in 1933 as a civilian employee and was commissioned an ensign in 1940.

As a C&GS commissioned officer, he served on various survey ships and combined geodetic control, hydrographic, and photogrammetric surveys. From 1957 to 1961, he was chief of a geodetic project engaged in establishing ground control for water resources mapping of the Blue Nile River Basin in Ethiopia. He was awarded the Department of Commerce Gold Medal, the Department's highest honor, for his service on this project.

Following his return from Ethiopia, Jones was for two years Assistant Chief of the Division of Geodesy at Survey headquarters. He next served aboard the ship SURVEYOR, first as Executive Officer and then as Commanding Officer. In 1966, he became Associate Director, Office of Hydrography and Oceanography. From January 1967 to September 1968, he served as Associate Administrator of the Environmental Science Services Administration, NOAA's predecessor. He was then named Director of the Coast and Geodetic Survey. When NOAA was created and the Coast and Geodetic Survey became the National Ocean Survey, he was nominated by President Nixon as Director and has served in that capacity since.

Admiral Powell received an engineering degree from the University of Texas in 1938. He joined the Coast and Geodetic Survey in 1942, and served in World War II as a regimental survey officer. After the war, he served aboard various ships and with numerous field parties in the United States. In 1963, he was assigned to the Survey's Ship Construction Group. He was awarded the Department of Commerce's Gold Medal.

In 1968, he was appointed Director of the Survey's Atlantic Marine Center in Norfolk, Virginia, and was promoted to the rank of Rear Admiral. He also served as the Survey's East Coast field director. In 1971, he was appointed to his present position.

Captain Taylor was graduated from the University of Massachusetts with a degree in civil engineering, and subsequently earned a Master of Science degree in geodetic science from Ohio State University. He joined the Survey as a deck officer in 1950, serving on several ships and with field parties ashore. He served as satellite triangulations officer at Survey headquarters, and for his work in the satellite triangulation system was awarded the Commerce Department's Gold Medal in 1965. He was assigned to the command of the Survey Ship PATHFINDER in 1969, and was promoted to the rank of captain. In 1970, he became Chief of Operations and Requirements in the Survey's Office of Hydrography and Oceanography. In 1971, he was appointed Deputy Associate Director for the Survey's Office of Fleet Operations.

all in the family

PERSONNEL NOTES

Captain Miller J. Tonkel has been assigned to the Office of the Oceanographer of the Navy, where he serves as Acting Director of Marine Science Affairs in the Office of International and Interagency Affairs. He is the first from NOAA to be assigned to a major Navy position. Captain Tonkel's last post was command of the NOAA Ship OCEANOGRAPHER.

Dr. H. Geoffrey Moser and **Dr. Elbert H. Ahlstrom,** fishery biologists at the National Marine Fisheries Service Southwest Fisheries Center Laboratory, La Jolla, Calif., have won the Wildlife Society's award for the outstanding American fishery research paper of 1971.

Donald B. Munro, formerly stationed at Jackson, Miss., has been appointed to head the Lake Charles, La., office of the National Weather Service.

Dr. David Q. Wark, senior scientist of the National Environmental Satellite Service Satellite Experiment Laboratory, has won the Robert M. Losey Award, presented annually by the American Institute of Aeronautics and Astronautics. The award was given to Dr. Wark for "initiative, creativity, and effective leadership of a 12-year team effort which produced an operational system of worldwide aerological observations."

Richard D. Tarble, who has been hydrologist in charge at the Sacramento, Calif., River Forecast Center since 1963, has accepted a two-year WMO transfer to Malaysia, where he will assist in developing a flood warning program.

Lt. (j.g.) Stewart McGee has joined the computer processing group at NOAA's Earthquake Mechanism Laboratory in San Francisco, Calif., where he will be concerned with computer processing of earth strain and tilt data sampled by instruments in California, Nevada, and Alaska in a research program aimed at improving understanding of tectonic processes. He was formerly assigned to the NOAA Ship MT MITCHELL.

Lt. Cdr. Leonard E. Pickens is the new Executive Officer of the NOAA Ships RUDE & HECK. A commissioned officer for the past nine years, he served previously on the Operations staff of the Atlantic Marine Center, Norfolk, Va.

Jack W. Gehringer, who recently completed a detail in the National Marine Fisheries Service headquarters in Washington, D. C., after serving as an associate director in the Gulf and South Atlantic Region since April 1970, has been named Director of that Region. He succeeds Richard T. Whiteleather, who retired after 36 years of service.

Frederick P. Helgeson is now official in charge of the Weather Service Office in Parkersburg, W. Va. He had been an aviation observation specialist in the Data Acquisition Branch of the NWS Eastern Region Headquarters.

Paul N. Sund, formerly a coordinator for program activities at the National Marine Fisheries Service, Washington, D.C., headquarters, has been transferred to Tiburon, Calif., where he will serve as coordinator of all "Platforms of Opportunity" programs conducted by NMFS.

D. R. Davis is the new meteorologist in charge of the National Weather Service Office at Tallahassee, Fla. Formerly the agricultural meteorologist assigned to the University of Florida Agricultural Research and Education Center in Quincy, Mr. Davis was engaged in studies concerning plant growth, plant diseases, and insect problems as related to weather.

Lt. Cdr. John W. Carpenter is the SURVEYOR's new operations officer. Since becoming a commissioned officer in 1964, he has served aboard the WHITING and PEIRCE and as Chief of Field Parties G-21 and G-17.

Capt. Herbert R. Lippold, Jr., is now commanding officer of the NOAA Ship OCEANOGRAPHER. He had been commanding officer of the PATHFINDER.

Cdr. Kelly E. Taggart, formerly executive officer of the FAIRWEATHER, has been assigned to the same post on the OCEANOGRAPHER.

Cdr. Ray M. Sundean, the OCEANOGRAPHER's new operations officer, was formerly director of the National Tsunami Warning Center in Honolulu.

Cdr. George M. Poor has been assigned to command the NOAA Ship McARTHUR. Previously, he was projects officer in the Operations of the Atlantic Marine Center, Norfolk, Va.

Dr. James R. Wait, senior scientist and consultant to the directors of the Institute for Telecommunication Sciences and its parent organization, the Office of Telecommunications, has transferred to NOAA as a consultant to Environmental Research Laboratories director Wilmot N. Hess, a position he formerly held in ESSA.

Charles M. Fuss, Jr., has been appointed chief of the new Enforcement and Surveillance Division, in the National Marine Fisheries Service Southeast Regional Office at St. Petersburg, Fla. Mr. Fuss has held assignments in the Southeast Region for the past 12 years.

Dwight B. Kline, who has served as deputy director of the Environmental Research Laboratories' Office of Programs in Boulder, Colo., since 1966, has been appointed deputy director of the National Severe Storms Laboratory in Norman, Okla.

Dr. Jerry M. Davis, a meteorologist at the National Meteorological Center in Suitland, Md., since 1968, has been named Climatologist for the State of Ohio.

Morton Bailey is the new state climatologist for North Dakota. For the past three years, he was assigned to a technical assistance program designed to upgrade the weather services of Zambia, Africa. His previous assignments included being a research analyst at the National Climatic Center, Asheville, N.C., and also in Praetoria, Union of South Africa.

Robert V. Ochinero, who has been Acting Director of the Environmental Data Service's National Oceanographic Data Center since October 1970, became Director of the Center on November 28.

Lt. (j.g.) Albert E. Theberge is the new chief of geodetic field party G-47. He recently completed an assignment on the NOAA Ship SURVEYOR.

Lt. Cdr. Merritt N. Walter of the NOAA Corps is now also a Captain in the U.S. Merchant Marine, a distinction he achieved by qualifying for a master's license from the Coast Guard after three months of instruction and eight days of examinations.

Charles B. Haegele, mechanical engineer in the National Weather Service Engineering Division's Facilities Engineering Branch, recently received a $1000 special achievement award for excellent performance in support of Engineering Division and NWS programs.

Dr. Joseph Smagorinsky, Director of the Geophysical Fluid Dynamics Laboratory, has won the Carl-Gustaf Rossby Research Medal, the highest honor given by the American Meteorological Society. Dr. Smagorinsky was cited "for creative leadership in numerical modeling of the general circulation of the atmosphere."

Vincent J. Oliver, Chief of the NESS Applications Group, received the AMS award for applied meteorology, for his innovative contributions over the past three decades in the application of new meteorological observations and theory to the problem of weather forecasting and for his creative use of meteorological satellite data.

Dr. Francis W. Reichelderfer, chief of the U.S. Weather Bureau from 1938 to 1963, received a special AMS award, in appreciation of his lifetime of devotion to the AMS as charter member, fellow, and president, and for his countless contributions to the weather services of the United States and the world.

Dr. Harris B. Stewart, Jr., Director, and **Jack W. Kofoed,** Assistant Director, Atlantic Oceanographic and Meteorological Laboratories, have been appointed to the scientific advisory group of the U.S. Coast Guard.

Joan Degener Bartlett, writer-editor in the ERL Publication Services Section, has been named Colorado's outstanding young woman for 1971 by the Outstanding Young Women of America.

James Giraytys, chief of the NWS Data Acquisition Division's Requirements and Evaluation Branch, has been designated as a U.S. member of the WMO Commission for Instruments and Methods of Observation.

Dr. J. Perry Lane and **Burton L. Tinker** of the National Marine Fisheries Service have been elected treasurer and secretary, respectively, of the New England Fisheries Institute. Dr. Lane is fisheries extension coordinator of the NMFS Northeast Region. Mr. Tinker is a research chemist at the Atlantic Fishery Products Technology Center.

William D. Kleis of ERL's Office of Programs is the Department of Commerce representative on the Interagency Coordinating Panel for the 1973 solar eclipse, June 30, 1973. He is responsible for coordinating all Commerce activities and experiments relating to the eclipse.

Captain Gerard E. Haraden has been named Commanding Officer of the NOAA Ship RAINIER. Most recently he was chief of operations at the NOAA Pacific Marine Center in Seattle, Wash.

Donald H. Pack has been named director of NOAA's Geophysical Monitoring for Climatic Change program, managed by the ERL Air Resources Laboratory. The program is designed to measure trace constituents in the atmosphere and to determine their trends over long periods of time.

Five FLARE Projects Completed As Program Reaches Halfway Mark

FLARE (the Florida Aquanaut Research Expedition), NOAA's most enterprising underwater investigation to date, completed its first phase March 3.

The project was scheduled to resume March 28 and continue through mid-April.

The five studies completed on Phase One used the services of scientific personnel from several components of NOAA, the University of North Carolina, the University of New Hampshire, the University of Miami, Duke University, and the Woods Hole Oceanographic Institution.

Missions centered on reaction of fish to traps, the effect of a human community on reefs, the geology and oceanography of reefs, and comparison of manmade undersea structures with natural reefs.

All participants said they were impressed with the concept of FLARE, in which the 500-ton LULU provided transport and life support for the portable habitat EDALHAB, anchored for four-day intervals in 45 feet of water for use as a working platform for seafloor explorers. LULU, on loan from the Woods Hole Oceanographic Institution, was developed originally as the mother ship for the deep-diving ALVIN, but proved equally capable as a carrier for EDALHAB. The habitat was constructed and modified, with the aid of NOAA Sea Grant Funds, by students at her home base, the University of New Hampshire. FLARE is under the direction of NOAA's Manned Undersea Science and Technology office.

First to dive for FLARE were fishery researchers William L. High, Ian E. Ellis, and Gary Loverich of NOAA's National Marine Fisheries Service Seattle laboratory. The site was near Elliott Key (22 miles south of Miami). Participants said they collected data of significant value to a long-term study of behavioral patterns of fish toward commercial traps.

The second team—on a two phase study—consisted of physiologist Dr. J. Morgan Wells, his oceanographer wife Anna, and FLARE's scientific coordinator, John G. VanDerwalker. (The Wells, incidentally, were first-man-wife team to live and work—under saturated conditions—on the U.S. Continental Shelf.) The subject of their investigations was the "community metabolism" of a relatively uncontaminated reef compared with that on a reef under the influence of human pollutants. Findings were that the first reef—at Elliott Key—was in a healthy condition, though production did not seem as great as that found on comparable reefs in the Caribbean and the Pacific. At the second reef examined, a few miles off Miami Beach, findings were dramatically different: Wells and VanDerwalker said that the reef was nearly colorless, almost devoid of the algae that nourishes coral life, and close to death. They also reported that the Miami Beach reef seemed to have a strange ecosystem, different from any they had observed before. In preliminary statements, the team said that heavy siltation present in Miami Beach waters—from dredging, shore construction, turbid inflow from Biscayne Bay, natural runoff, and sewage outflow—undoubtedly made a large contribution to the abnormal conditions observed.

The third team—geologists John A. Gifford, Stephen Cawthon, and Eric Frehsee, from the University of Miami's Rosenstiel School of Marine and Atmospheric Science—saw distinct evidence of reef shrinkage at the Elliott Key site. Findings suggested that the reef had probably been under water cover of only five or ten feet several thousand years ago, but now is at a depth of 60 feet. Decreased photosynthesis as sealevels over the reef increased undoubtedly caused a diminishing of reef production.

The fifth FLARE dive was completed by biologists Harold L. Pratt, Kenneth Pecci, and Clifford Newell, from NOAA's fisheries laboratories at Rhode Island and Maine. The trio studied fish populations inhabiting an artificial reef emplanted by FLARE scientists a month before, and a nearby long-established natural reef. They said they were able to establish a "blueprint" of populations, against which the same populations will be measured on the final FLARE dive, scheduled for mid-April, in which fisheries researchers from the NMFS sport fisheries laboratory at Sandy Hook, N.J. will complete the two-part investigation.

Probability of Precipitation Predicted by NMC Computers

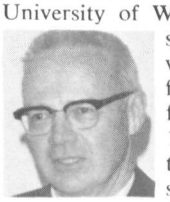
The National Weather Service's Techniques Development Laboratory has developed an automated system that produces probability of precipitation forecasts out to 60 hours for the conterminous United States. On January 1, the automated system replaced the subjective system, the automated forecasts being sent from the National Meteorological Center to forecast offices twice a day via facsimile. Within the next few years, it is planned to expand the program to Alaska, Hawaii, and Puerto Rico.

The research and development effort that led to automation of the probability-of-precipitation forecasts was headed by Dale A. Lowry, with assistance from Dr. Harry R. Glahn, George Hollenbaugh, and Lt. (j.g.) John Annett, NOAA. Verification over a 12-month test period showed the automated forecasts, based on a method called PEATMOS (Primitive Equation and Trajectory Model Output Statistics), to be superior to those previously prepared manually by the National Meteorological Center.

Associate Directors Appointed to NMFS

Three Associate Directors of the National Marine Fisheries Service have been appointed recently: Dr. William F. Royce for Resource Research; Joseph Slavin for Resource Utilization; and Dr. Robert F. Hutton for Resource Management.

Dr. Royce had been Associate Dean of the school of Fisheries, University of Washington, Seattle, since 1967. He was with the Federal fisheries service from 1942 until 1958 when he left to become Professor of Fisheries and Director of the University of Washington's Fisheries Research Institute. He frequently acted as a fisheries consultant to a number of developing nations in Africa, Latin America, and the Middle East. For several months during 1967, while on leave from the University, he was in Rome as fishery officer for the UN's Food and Agriculture Organization, advising on fishery education and training programs in East Africa. He was also an advisor on salmon problems to the United States section of the International North Pacific Fisheries Commission.



In his new position, Dr. Royce is responsible for overall management of resource research and development at NMFS Fisheries Centers.

Mr. Slavin has been with NMFS (formerly the Bureau of Commercial Fisheries) since 1954, when he joined its technological laboratory in East Boston, Massachusetts. After the facility was moved to Gloucester, Mass., Mr. Slavin functioned as laboratory director from 1961 to 1966. He then joined the Washington headquarters staff as Assistant Director for Industrial Research, later became Assistant Director for Utilization and Engineering, and more recently was Assistant Director for Operations.

As Associate Director for Resource Utilization, his responsibilities include programs of economic and marketing research related to fishery products including demand and supply projections, benefit cost studies, and foreign trade analyses; programs of collection, analysis, compilation, and dissemination of fishery statistics and market news; programs to assist the fishing industry through financial assistance in the form of loans, mortgage and loan insurance, and subsidies; programs of microbiological, chemical, and technological research to improve the quality and use of fishery resources; a voluntary national program of inspection and certification of fishery products; and programs to improve marketing practices and lessen the effects of supply-demand imbalances.

Dr. Hutton was Executive Secretary of the American Fisheries Society for the past six years.

NMFS operations within his jurisdiction are programs to accelerate efforts in the State-Federal Fisheries Management System; enforcement of fishery regulations prescribed by international agreements applicable to U.S. citizens; programs of financial assistance providing Federal funds for certain fishery programs by the States and other non-Federal interests on a cost-sharing basis; fishery extension activities; water resources programs relating to environmental protection of estuaries; and enforcement and surveillance activities to protect U.S. fisheries resources from foreign encroachment. He also is responsible for the Pribilof Island Program and the management of the Columbia River Development Program.

Prior to being named the American Fisheries Society's first full time Executive Secretary, Dr. Hutton was Biologist in Charge at the Florida State Marine Laboratory, St. Petersburg, Fla., from 1955 to 1962, and Chief of Marine Biology with the Massachusetts Department of Natural Resources from 1963 to 1965.

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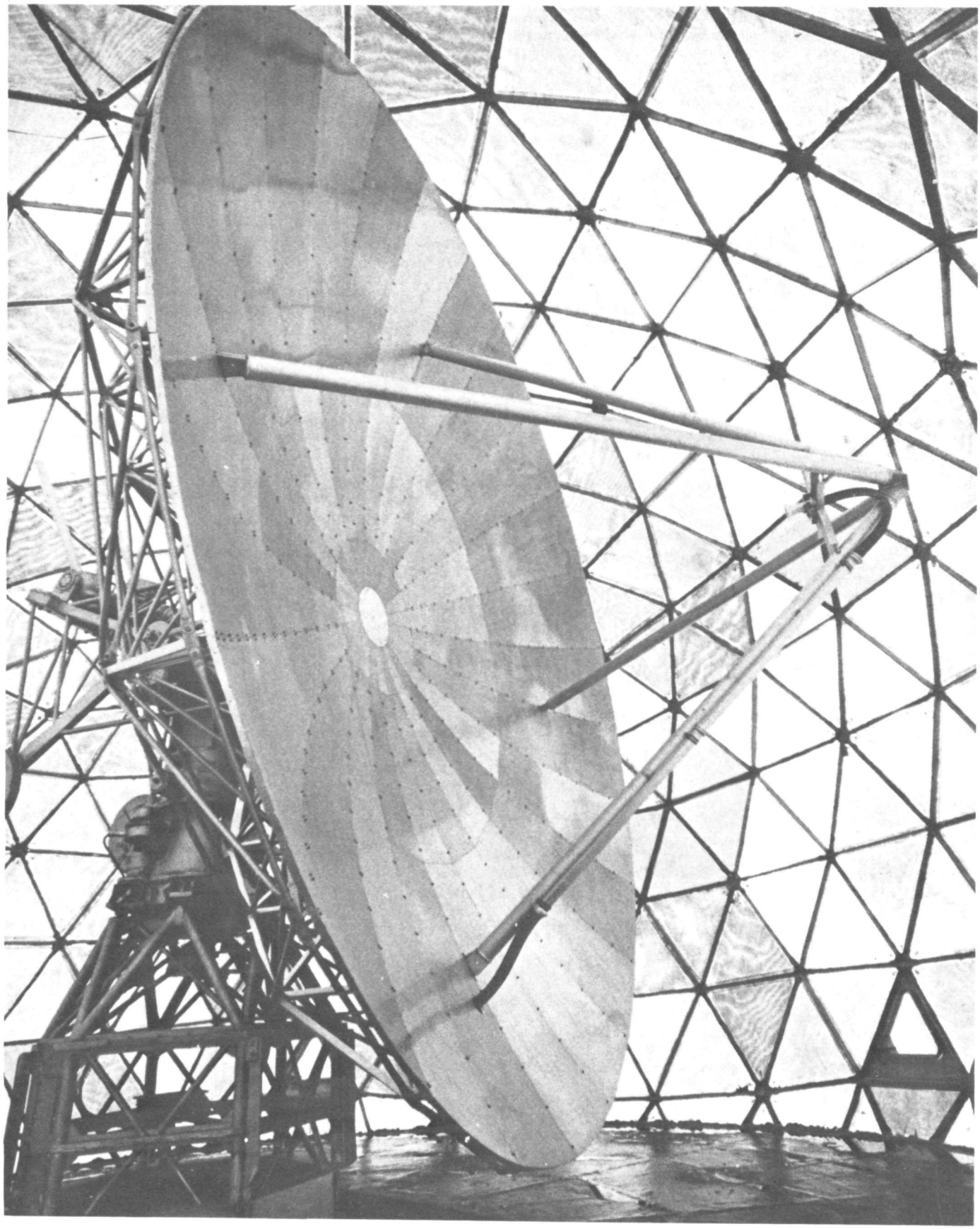
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