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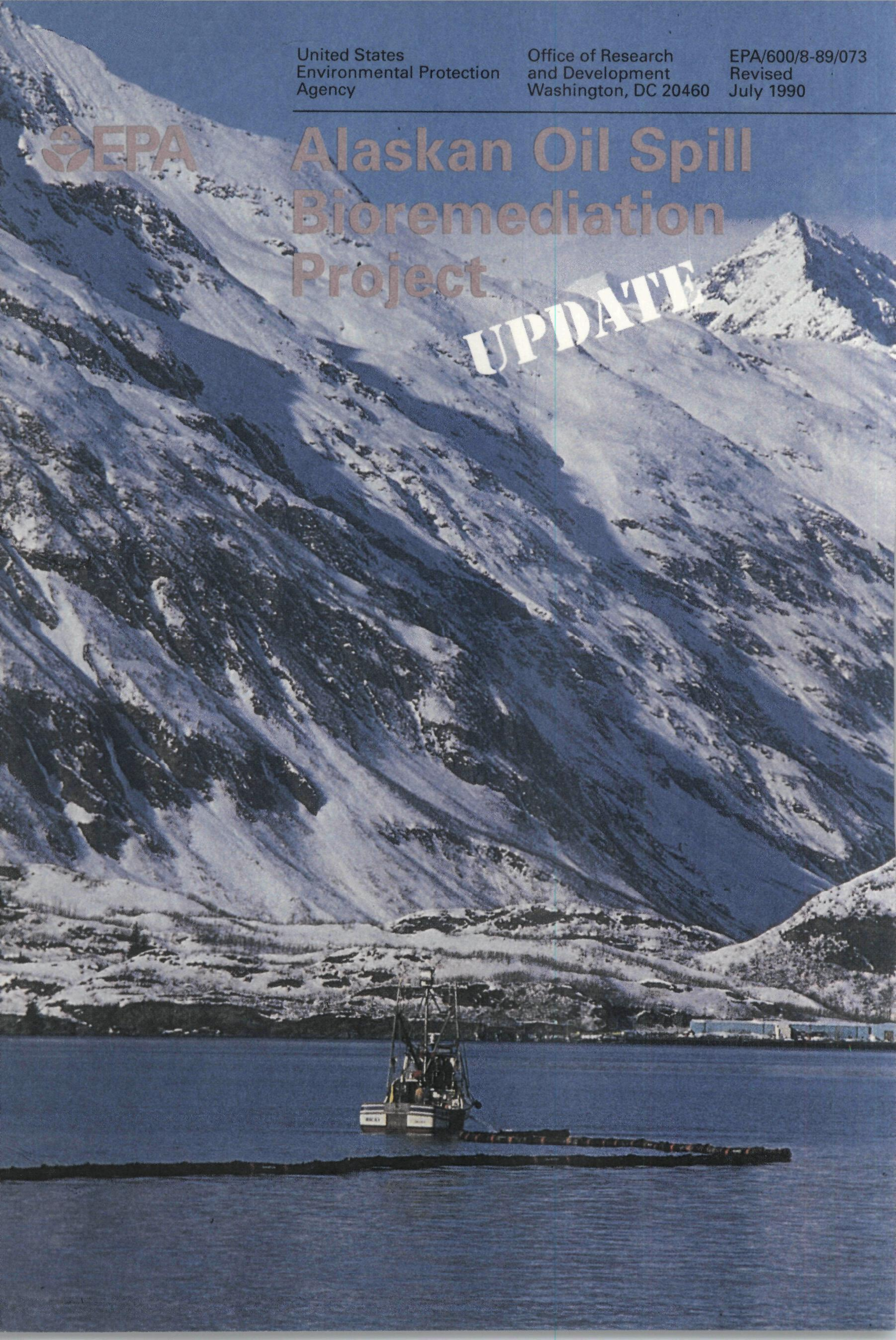
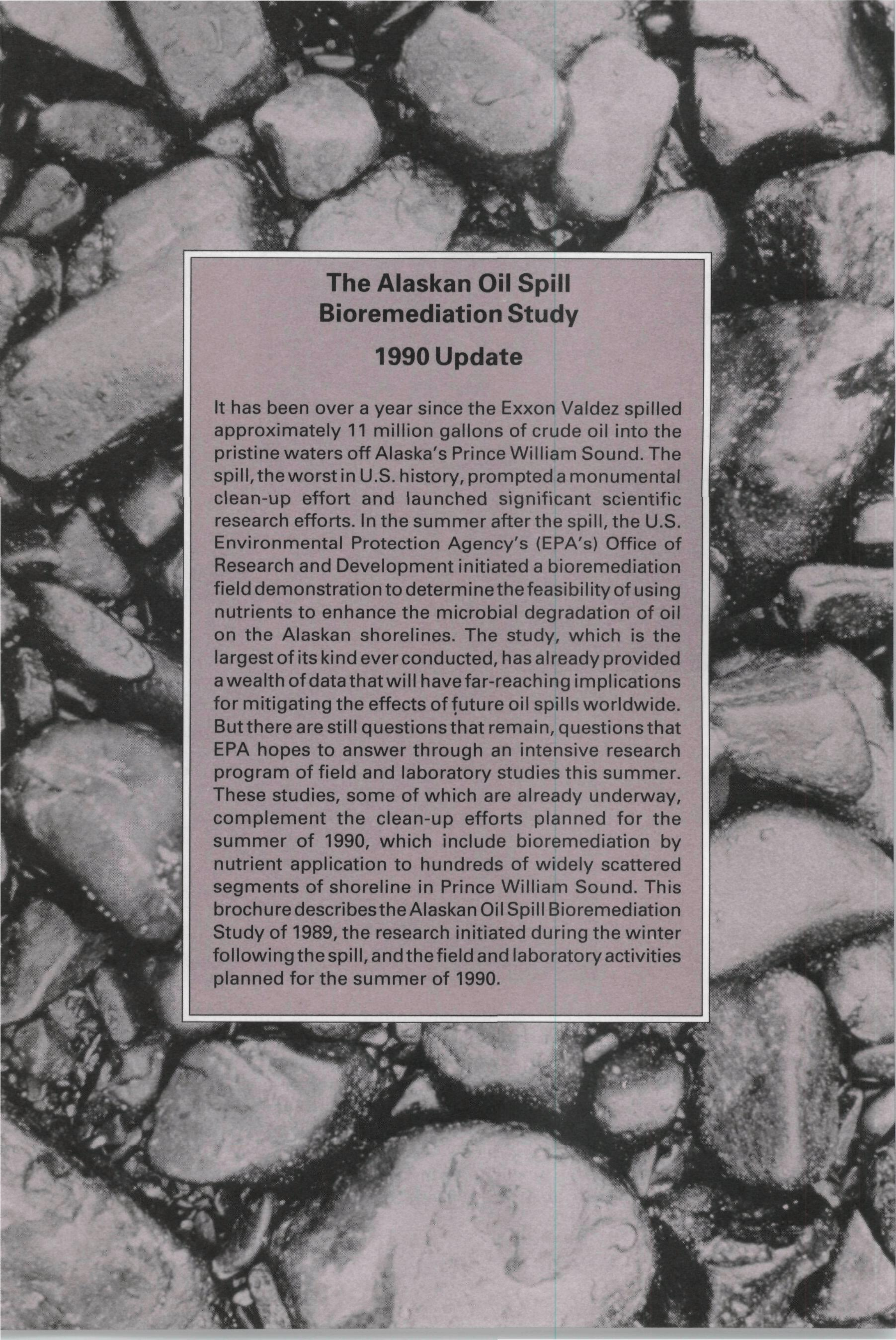
Alaskan Oil Spill Bioremediation Project

UPDATE

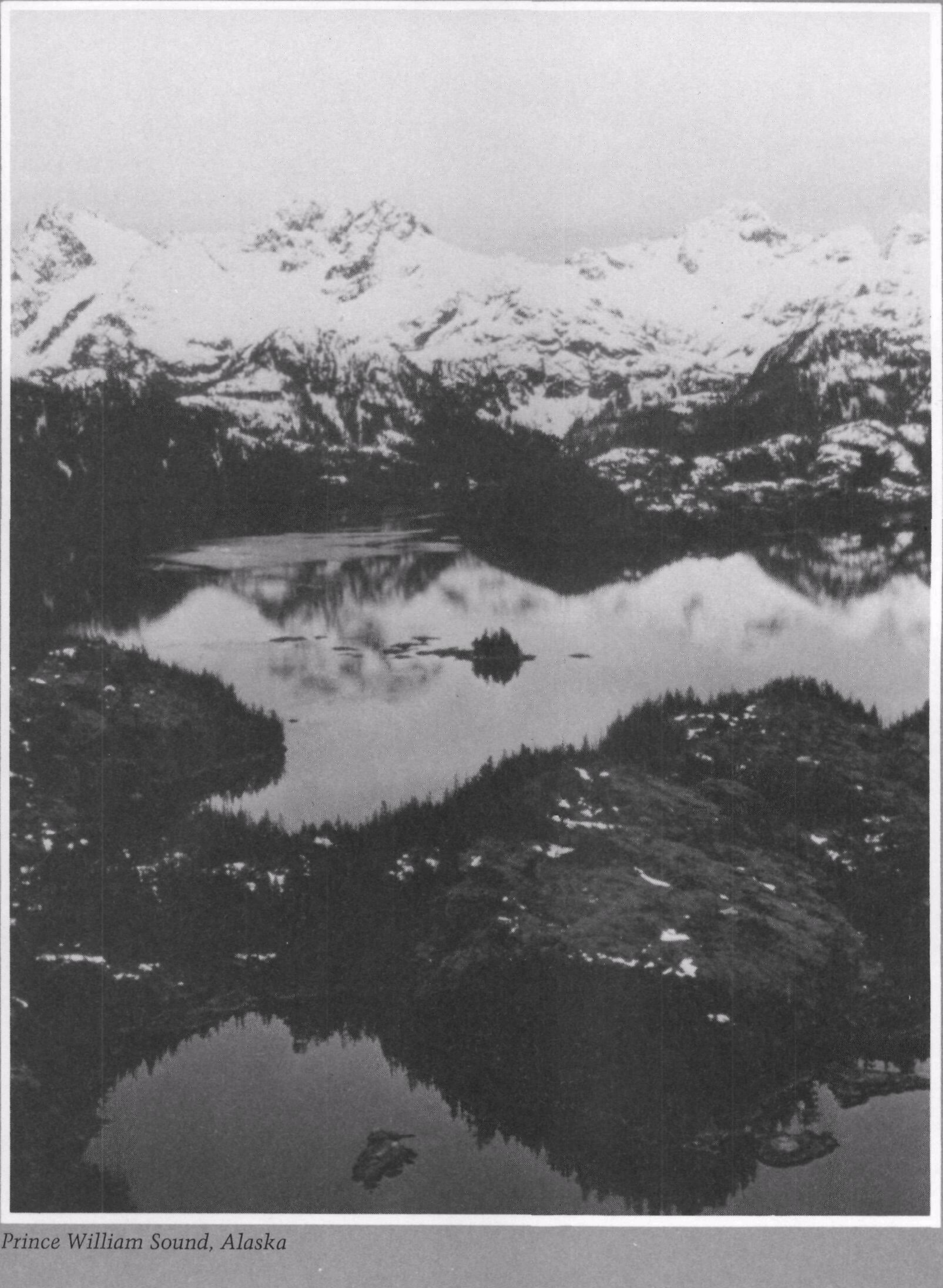




The Alaskan Oil Spill Bioremediation Study

1990 Update

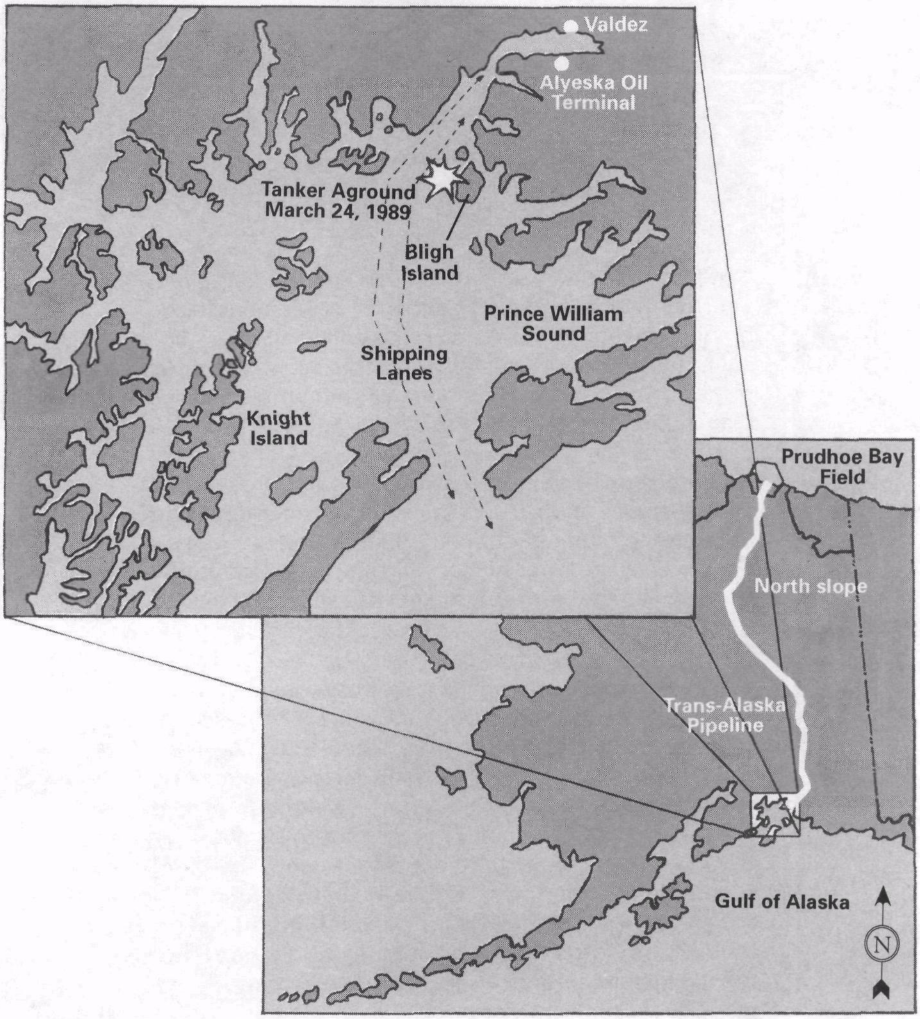
It has been over a year since the Exxon Valdez spilled approximately 11 million gallons of crude oil into the pristine waters off Alaska's Prince William Sound. The spill, the worst in U.S. history, prompted a monumental clean-up effort and launched significant scientific research efforts. In the summer after the spill, the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development initiated a bioremediation field demonstration to determine the feasibility of using nutrients to enhance the microbial degradation of oil on the Alaskan shorelines. The study, which is the largest of its kind ever conducted, has already provided a wealth of data that will have far-reaching implications for mitigating the effects of future oil spills worldwide. But there are still questions that remain, questions that EPA hopes to answer through an intensive research program of field and laboratory studies this summer. These studies, some of which are already underway, complement the clean-up efforts planned for the summer of 1990, which include bioremediation by nutrient application to hundreds of widely scattered segments of shoreline in Prince William Sound. This brochure describes the Alaskan Oil Spill Bioremediation Study of 1989, the research initiated during the winter following the spill, and the field and laboratory activities planned for the summer of 1990.



Prince William Sound, Alaska

Back Cover:
From the air, a bioremediated test plot resembled a clean rectangle etched upon the surface of the beach. The cobblestone plot, which was located in Snug Harbor, was treated with oleophilic fertilizer during the summer of 1989.

Alaska and Prince William Sound

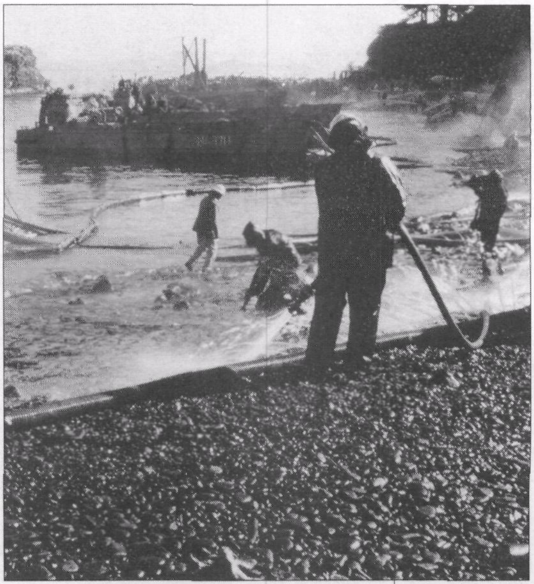


ALASKA - The name comes from an Aleutian word meaning "great land." If laid on the 48 lower states, Alaska would cover nearly one-fifth of them. The state is great in resources as well as land mass. In 1968, enormous quantities of oil were discovered on Alaska's North Slope in Prudhoe Bay. In 1974, construction began on the Trans-Alaska Pipeline under the direction of the Alyeska Pipeline Consortium Co., which was formed by the seven firms that pump crude oil from the North Slope. The pipeline extends nearly 800 miles with its terminus in Valdez, Alaska, where a shipping complex and other facilities are located. Since the pipeline was built, approximately 9,000 shipments of oil have been transported through Prince William Sound.

The Aftermath of the Spill

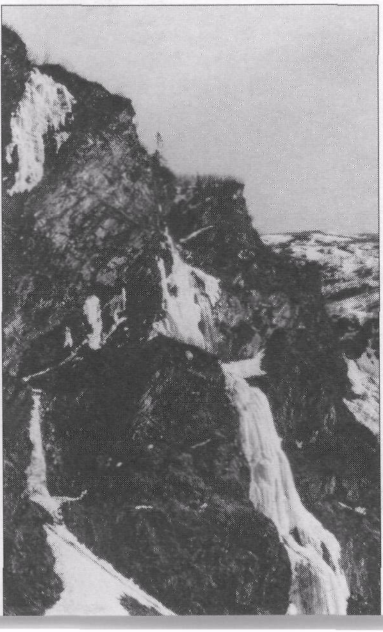
In March of 1989, the supertanker *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, Alaska, flooding one of the nation's most pristine and sensitive environments in less than 5 hours with approximately 11 million gallons of crude oil. The spilled oil affected up to an estimated 900 miles of shoreline in the Sound. These islands and their waters are home to a wide range of wildlife, including deer, black and brown bears, seals, otters, and whales, as well as an extensive array of birds and fish. Commercial salmon fish hatcheries are also located in the protected bays ringing the Sound.

In the short term, the oil spill has taken a toll on the area's diverse wildlife, and directly touched the lives of many Alaskans. While the long-term effects of the spill are still being evaluated, there is the potential for habitat and food chain disruption, as well as decreased survivability and reproductivity of animals exposed to the oil. These effects, while perhaps not immediately fatal to a given individual, have a direct bearing on the survival of the species as a whole and consequently of the ecosystem of which it is a member.



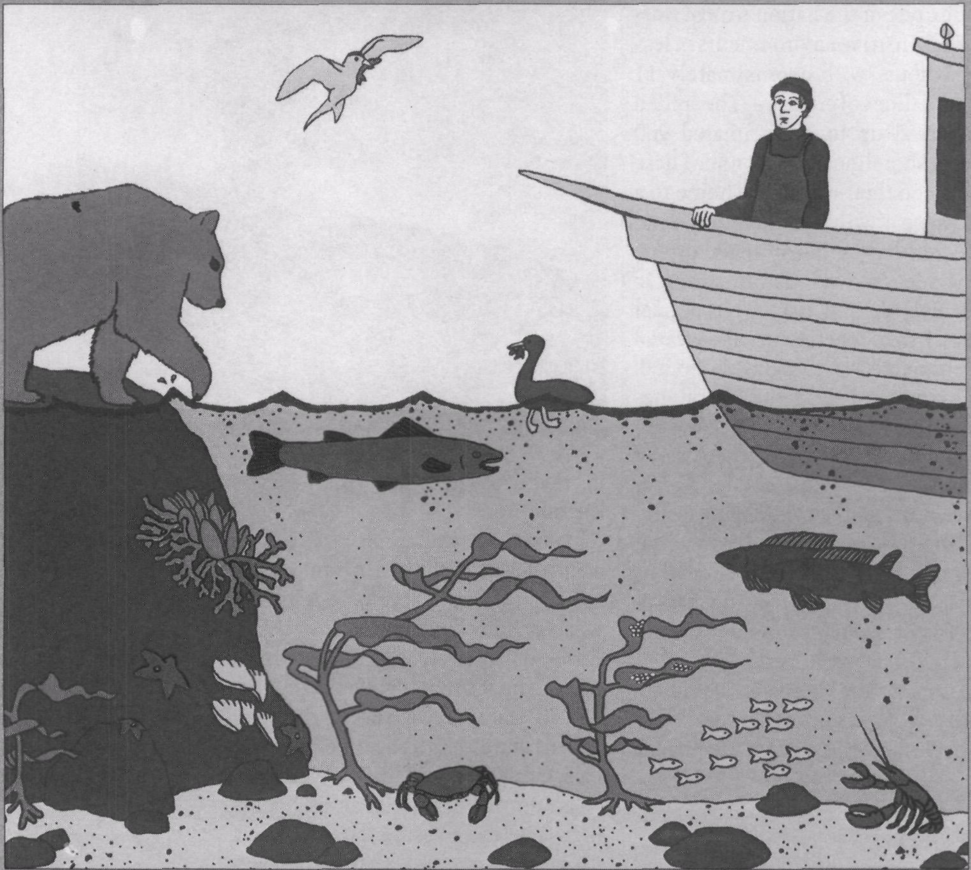
Workers used several techniques, including high-pressure spraying, to clean up the spilled oil in 1989.

In the immediate aftermath of the accident, attempts to clean up the spilled oil were hampered by bad weather and the remoteness of the location. Ultimately, a massive cleanup was organized that involved more than 10,000 individuals, several hundred vessels and aircraft, and highly specialized equipment. Many conventional clean-up techniques (such as booms, high- and low-pressure spraying, skimmers, and manual scrubbing) were employed to remove oil from the surface of the rocks and beaches. These techniques, however, were unable to remove all of the oil from the beaches, or oil trapped under rocks and in the matrix of beach sediments.



Glaciers have left their mark on the coastline of Prince William Sound. Coastal topography is often steep, and ranges from vertical cliffs to sand, pebble, and boulder beaches. In some areas, streams and snow melt also introduce large amounts of fresh water to the near-shore waters of the Sound.

The Effects of Oil on the Food Chain



A CHAIN OF EVENTS - Spilled crude oil has the potential to affect every level of the marine food chain. Floating oil may contaminate plankton, which includes algae, fish eggs, and the larvae of various invertebrates (such as oysters and shrimp). In turn, the small fish that feed on these organisms can become contaminated. Larger animals in the food chain (including bigger fish, bears, and humans) may then eat these contaminated fish. In addition, marine animals and birds may be exposed directly to oil in the water column, which they can ingest or get on their fur or feathers. Spilled oil may also prevent the germination and growth of marine plants and the reproduction of invertebrates, either by smothering or by toxic effects.

Enhancing the Cleanup with Bioremediation

To enhance the clean-up efforts, the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development (ORD) suggested that bioremediation might be useful. A panel of national and international expert scientists in the field of bioremediation was convened, which recommended that ORD conduct a field demonstration project to evaluate the feasibility of using bioremediation to assist in clean-up operations.

Bioremediation involves the use of microorganisms (such as bacteria) to enhance the "degradation" of oil and other types of chemicals. Scientists have observed that biodegradation occurs naturally in the environment after a spill of crude oil due to the presence of indigenous microorganisms. These microorganisms degrade the hydrocarbons found in the crude oil (which they use as a food source) into a harmless substance consisting primarily of carbon dioxide, water, and fatty acids.

A few days after the Alaskan spill, microorganisms began to multiply naturally in response to the presence of oil. With such a bounty of hydrocarbons, however, the ability of these microorganisms to degrade the oil was limited by the availability of nutrients (nitrogen and phosphorus). Without these nutrients, the microorganisms were unable to fully utilize the hydrocarbons as a food source.

Therefore, the panel of expert scientists that was convened recommended that ORD apply fertilizers to designated test beaches in Prince William Sound. These fertilizers would help the microorganisms to degrade the oil. The rationale behind this approach is that the greater the number of microorganisms or the greater the microbial activity, the greater the ability of the organisms to break down the oil and the faster the rate of degradation. Bioremediation has the potential to clean up the oil trapped beneath rocks and in the beach sediments, and has the added advantage of being less disruptive to the environment than conventional clean-up techniques such as pressure spraying.

A Cooperative Agreement

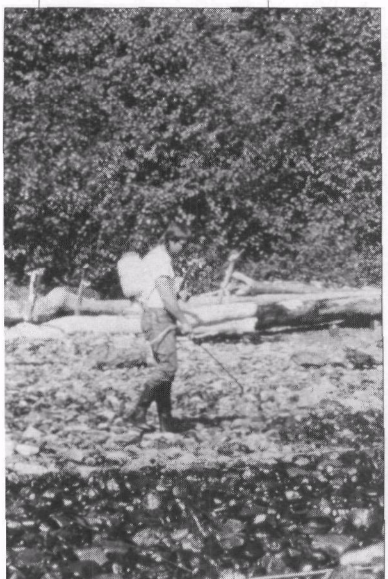
Because of the need for rapid response, ORD quickly drafted a research plan for the bioremediation field test and submitted it to EPA's Science Advisory Board (SAB). The SAB, which Congress established in the late 1970s to provide advice to EPA regarding the scientific and technical aspects of environmental problems and issues, approved the research plan with minor modifications. The SAB also stated that the project would be a significant contribution to future environmental research planning and technology.

ORD then approached Exxon and proposed a cooperative effort to conduct the bioremediation study under the Federal Technology Transfer Act of 1986. The Act encourages collaboration between the private and public sectors for the economic, environmental, and social benefit of the United States.

In early June of 1989, ORD entered into a formal cooperative agreement with Exxon to test the capability of bioremediation in treating contaminated beaches in Prince William Sound. To ensure the independence of study results, EPA provided the technical expertise to carry out the bioremediation project, and was responsible for oversight and management of the study. EPA also agreed to provide supplemental resources for any other efforts that would be necessary to make the technology useful in the cleanup of future spills. Exxon paid for the logistical support directly applicable to the study (such as lodging for the scientists and transportation from Valdez, Alaska, to the test sites) and for laboratory and field support. In 1989, EPA's contribution to the Alaskan Oil Spill Bioremediation Project was approximately $1.6 million and Exxon's share was about $3 million.

Snug Harbor

Scientists used backpack sprayers to apply the liquid oleophilic fertilizer to a test beach in Snug Harbor.

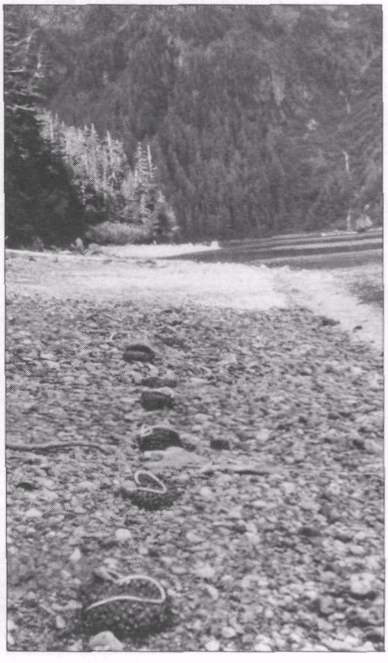


After planning and mobilizing staff and facilities, scientists surveyed beaches to find a suitable test area for the project. Snug Harbor, which is located on the southeastern side of Knight Island, was selected as the test site. The area is surrounded by mountains with steep vertical ascents and peaks of up to 2,000 feet. The shoreline, which was moderately oiled, had a reasonable uniformity of beach material (cobblestone, gravel, or sand). The test area was also sheltered from storms and subject to minimal freshwater runoff (streams and snow melt), which could interfere with the field tests. The degree of contamination at Snug Harbor simulated those conditions considered typical of a beach following physical washing (the primary clean-up procedure used by Exxon).

Nutrient application began on June 8, 1989. Two types of nutrient-rich fertilizers were applied to the test beaches:

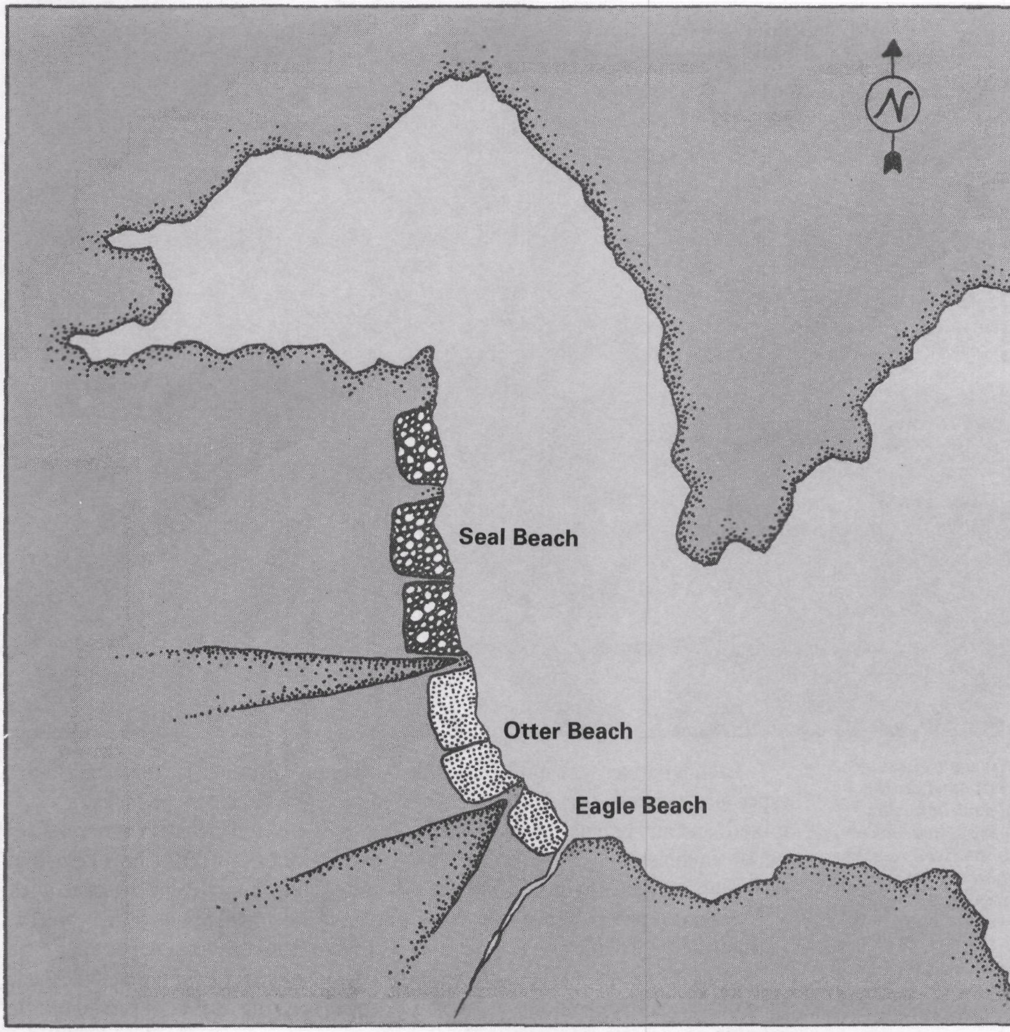
- A slow-release, water-soluble fertilizer, in which nutrients were slowly released and distributed to the oil-contaminated beach surfaces by rain and tidal action. Fertilizer "briquettes" (similar in size and weight to charcoal) were bagged in herring nets, placed on the beach surface, and anchored in the tidal zone with steel-reinforced rods.

- A liquid oleophilic fertilizer, in which the nutrients adhered to the oil covering the rock and gravel surfaces, thereby making nitrogen and phosphorus available at the site of microbial activity. This fertilizer was sprayed over the contaminated test areas.



Slow-release, water-soluble fertilizer briquettes were bagged in herring nets and anchored in the tidal zone on a test beach in Snug Harbor.

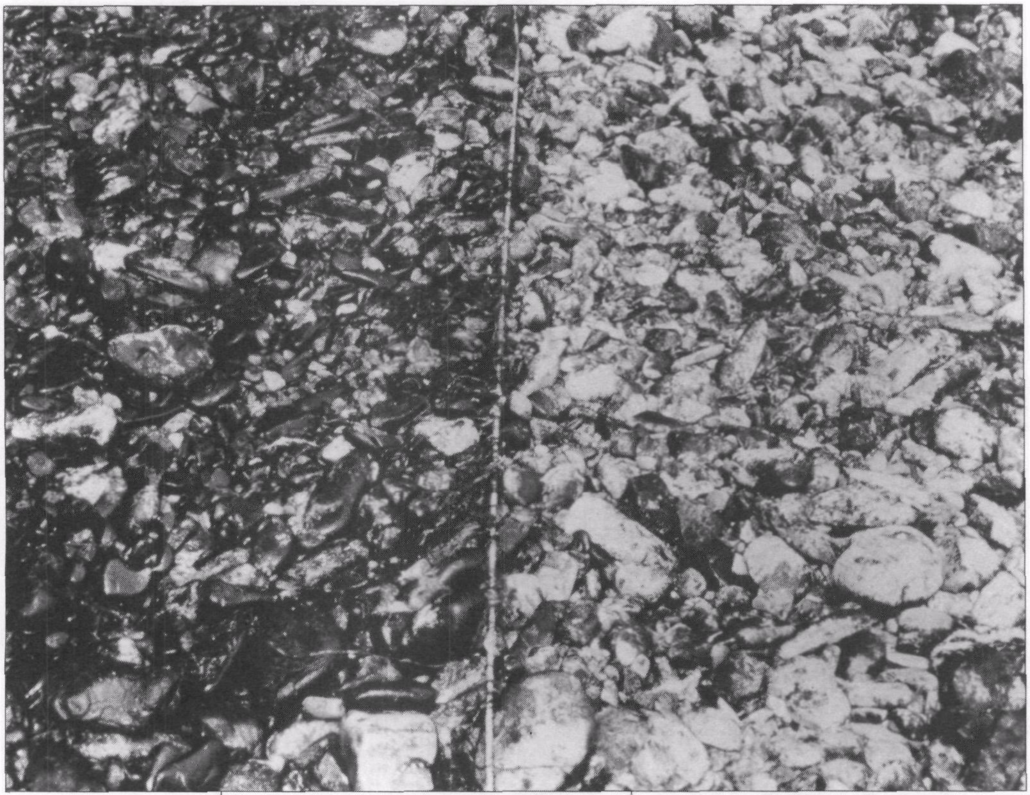
Snug Harbor



Snug Harbor Test Plots

Beach Name	Beach Type	Nutrient Application
Seal	Cobble	None (reference)
Seal	Cobble	Oleophilic
Seal	Cobble	Water-soluble
Otter	Mixed sand and gravel	Water-soluble
Otter	Mixed sand and gravel	Oleophilic
Eagle	Mixed sand and gravel	None (reference)

Snug Harbor is located on Knight Island in Prince William Sound, Alaska. A small promontory divides Seal Beach from Otter Beach, while a more conspicuous promontory divides Eagle Beach from Otter Beach.



A test plot in Snug Harbor where the oleophilic fertilizer was applied looked dramatically cleaner than an adjacent untreated plot.

Each fertilizer was applied to two types of beaches—one comprised of mixed sand and gravel; the other made up of cobblestone. Two "reference" test plots, where no nutrients were added, also were set up for comparison against the treatment plots.

Approximately 2 weeks after the oleophilic fertilizer was applied to the cobblestone beach plot, scientists observed visible reductions in the amount of oil on rock surfaces. This was particularly evident from the air, where the contrast with oiled areas surrounding the plot was dramatic. To the scientists who surveyed the test plot by helicopter, it looked as if a clean rectangle had been etched on the beach's surface. Close examination of this treated cobblestone plot verified that much of the oil on the rocks' surfaces was gone, although oil remained in the mixed gravel below the rocks.

EPA scientists also observed reduced amounts of oil in the mixed sand and gravel beach plot treated with oleophilic fertilizer within 2 weeks, though the difference between the treated area and its reference plot was not as striking as that observed on the cobblestone beach. This is because tides mixed up the sand and gravel, whereas the cobblestone remained relatively stationary. Therefore, the visual disappearance of the oil was less apparent in the sand and gravel plot. The oil below the beach surface was disappearing as well. All other plots (including those treated with only the fertilizer briquettes) appeared as oiled as they had been at the beginning of the field study.

Over the next 2 to 3 weeks, the

cleaned rectangle on the cobblestone beach remained clearly visible. The oil in the sand and gravel below the cobblestone persisted, but became less apparent over the course of the summer. The oleophilic-treated mixed sand and gravel plot also appeared increasingly cleaner than its untreated reference plot. Beaches treated with the fertilizer briquettes were relatively unchanged.

Toward the end of the summer season, the entire test area became steadily cleaner. Most of the areas surrounding the test plots were also cleaner; scientists attributed this to several storms and frequent rainfall, which helped replenish nutrients in this area and enhance the natural biodegradation processes. However, a heavily oiled area south of Snug Harbor that was never treated remained considerably contaminated, suggesting that nature alone could not account for the dramatic reduction of oil observed in the test area.

Passage Cove

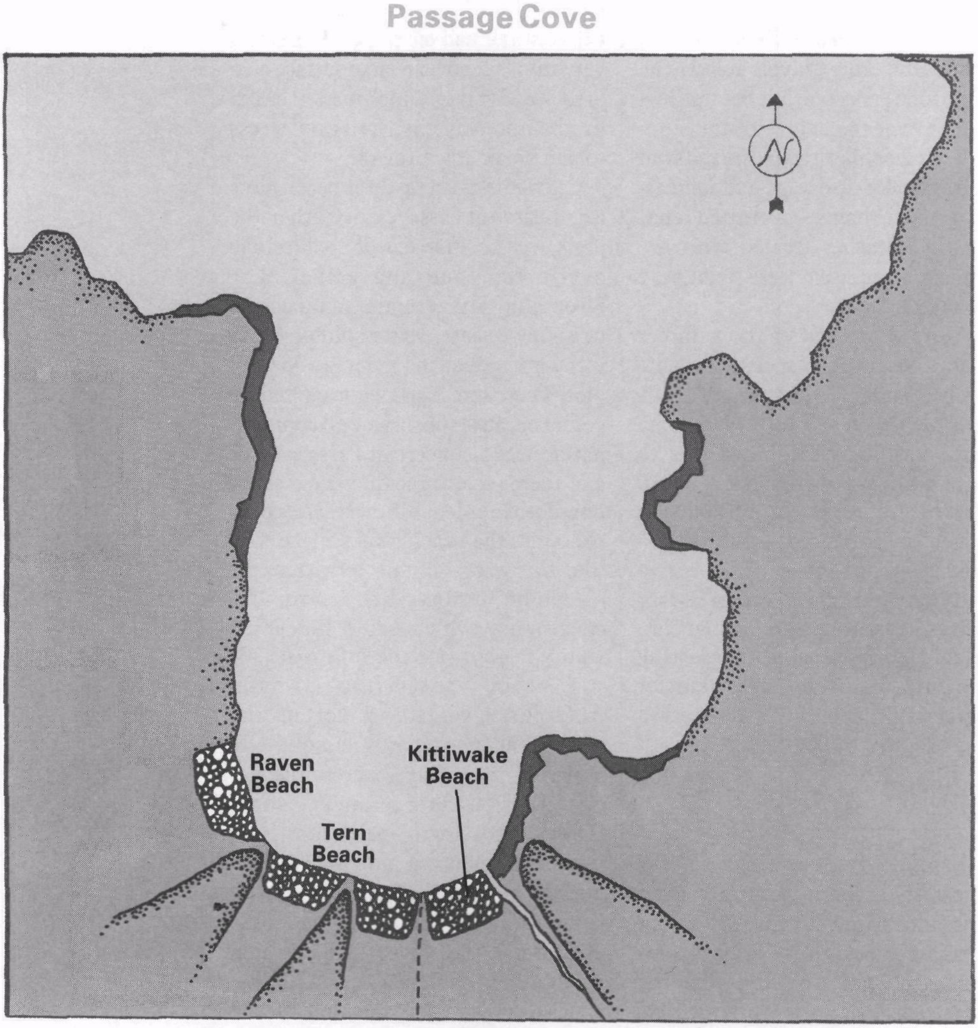
Based on the promising results of the initial field test at Snug Harbor and the absence of any adverse effects on the area's ecosystems, EPA recommended to Exxon in July that the bioremediation efforts be scaled up during the remainder of the summer. Passage Cove served as the main reference beach for a large-scale application of nutrients by Exxon clean-up crews, which commenced on August 1, 1989.

Passage Cove, which is located on the northwestern side of Knight Island, had been heavily oiled by the spill. Even though the site had been physically washed by Exxon clean-up crews, considerable oil remained on the shoreline and in the beach sediments. In fact, contamination was discovered as far as 2 feet below the surface. Scientists did find, however, that the physical washing had spread the oil into a very thin layer over a large surface area of rock and gravel, which made it easier for the microorganisms to gain access to and break down the oil.

Scientists set up three beach plots for research at Passage Cove. All of the plots were comprised of cobblestone overlaying sand and gravel. The oleophilic fertilizer and a granular form of a slow-release, water-soluble fertilizer were applied in tandem to one test plot. These fertilizers were applied together because subsurface oil contamination was a concern at Passage Cove and there were some questions about how deep the oleophilic fertilizer could penetrate the beach's subsurface. Unlike the water-soluble fertilizer, the oleophilic fertilizer has a syrup-like consistency which could hinder its ability to permeate the subsurface.

A third type of fertilizer, a fertilizer solution containing inorganic nitrogen and phosphorus dissolved in seawater, was sprayed across the second test plot by fixed sprinkler systems (similar to lawn sprinklers). An untreated reference plot was also set up for comparison purposes.

Within 2 weeks following the application of the oleophilic and water-soluble fertilizers, the treated beaches were considerably cleaner than the reference plot. Not only did the rock surfaces look cleaner, but the oil beneath the cobblestone was also disappearing. The beach plot treated with the fertilizer solution from the sprinkler system behaved in a similar manner, and became steadily cleaner. The reference plot showed no sign of oil loss. By the end of August, the treated plots looked equally clean. In contrast, the reference plot appeared very much as it did in the beginning of the field study. Oil in the subsurface still remained in all the test plots.



Passage Cove is located on Knight Island in Prince William Sound, Alaska. The test plot in Tern Beach was divided by a promontory.

Passage Cove Test Plots

Beach Name	Beach Type	Nutrient Application
Raven	Cobble over mixed sand and gravel	None (reference)
Tern	Cobble over mixed sand and gravel	Oleophilic and water-soluble
Kittiwake	Cobble over mixed sand and gravel	Nutrient solution sprinkler system

Hydrocarbon Analyses

To confirm that biodegradation was indeed taking place, scientists performed a variety of chemical analyses in the laboratory. These analyses indicated that over the summer, smaller and smaller concentrations of hydrocarbons were present in the oil samples taken at the test sites, thereby confirming that biodegradation was occurring *(see page 12)*. Scientists measure hydrocarbon concentrations through the use of gas chromatography. Oil is really a mixture of many different hydrocarbons, each with a specific boiling point. A boiling point is the temperature at which a compound will "volatilize" or turn to vapor. Gas chromatography capitalizes on the differences in boiling points among different hydrocarbons to separate, identify, and indicate the relative concentration of each of these components in crude oil.

Ecological Monitoring

Ecological monitoring studies were conducted concurrently with the fertilizer application tests at both Snug Harbor and Passage Cove. Although dilution and tidal mixing should minimize the potential for adverse ecological effects, scientists were concerned that certain components of the oleophilic fertilizer could be toxic to some marine species. In addition, algal blooms (excessive growth of algae in a body of water) could occur as a result of the sudden availability of nitrogen and phosphorus. Too many nutrients in a water body reduce the amount of oxygen present, thereby favoring plant life over animal life.

To determine the potential toxicity of oleophilic fertilizer to native organisms, a wide range of species (including stickleback fish, Pacific herring, silver salmon, mussels, oysters, shrimp, and mysids) was tested. EPA scientists collected samples of seawater directly over the beaches that had just been treated with a combination of the oleophilic and water-soluble fertilizer (a "worst-case" scenario).

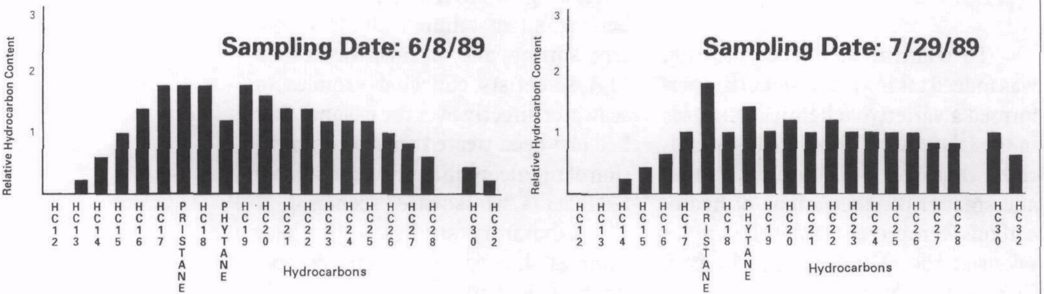
Laboratory studies with these samples showed that certain components of oleophilic fertilizer are mildly toxic to the most sensitive marine species (oyster larvae) where there is no dilution by tidal action. Oyster larvae are two orders of magnitude more sensitive than salmon. The potential toxicity of the fertilizer to salmon is a key concern since these fish spawn in Prince William Sound. The circumstances of fertilizer application, however, are such that the potential to adversely affect marine and terrestrial life is very unlikely. Scientists also found that adding nutrients to oiled shorelines did not cause any increases in algae, or any measurable nutrient accumulation in adjacent embayments.

EPA scientists also placed mussels in cages just offshore from the fertilizer-treated beaches and monitored them to determine if any toxic substances were accumulating in their tissues due to the release or breakdown of the oil. No oil was detected in the mussel tissues, and no oil was observed in the water offshore from the test areas.

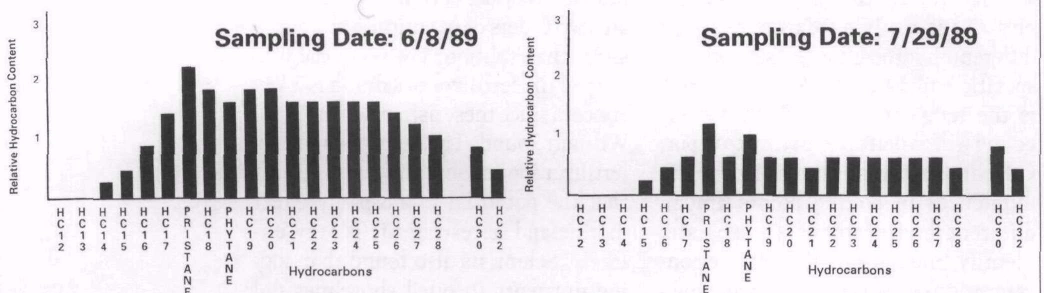
Microcosms

Microcosms were constructed on board a fishing vessel to provide supplemental information to the field demonstration project. Microcosms are designed to simulate naturally occurring processes on a smaller scale. They have the advantage of providing backup information in the event some unfore-

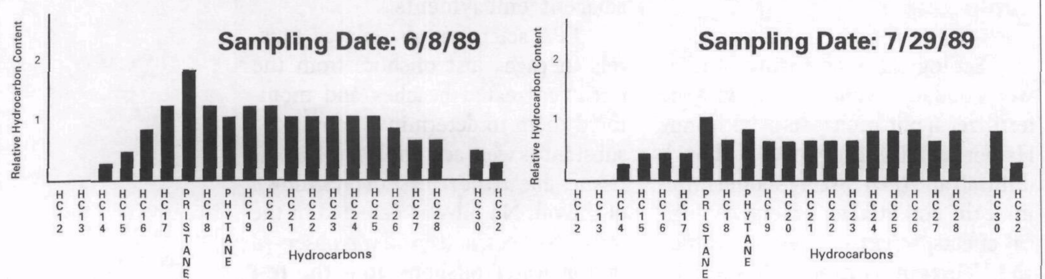
Snug Harbor-Mixed Sand and Gravel-Untreated Beach



Snug Harbor-Cobble-Water Soluble Fertilizer



Snug Harbor-Mixed Sand and Gravel-Oleophilic Fertilizer



HYDROCARBON ANALYSES - These figures illustrate how the composition of oil extracted from Snug Harbor test plots changed from early June to late July of 1989. Crude oil is a complex mixture of many compounds, including numerous hydrocarbons. Hydrocarbons, as the name implies, are made up of chains of carbon and hydrogen atoms. The numbers along the bottom of the graphs refer to the number of carbons in each hydrocarbon chain in the samples of crude oil. The height of the bar indicates the relative concentration of each hydrocarbon in the sample.

While all of the July chromatographs show reduced amounts of hydrocarbons compared to the June graphs (indicating that degradation was taking place), the treated plots show more pronounced reductions relative to the untreated reference plot, indicating that degradation was enhanced in the treated plots.

seen complication results in the field data. The microcosms also allow scientists to test bioremediation concepts under idealized conditions to better understand what is happening in the field.

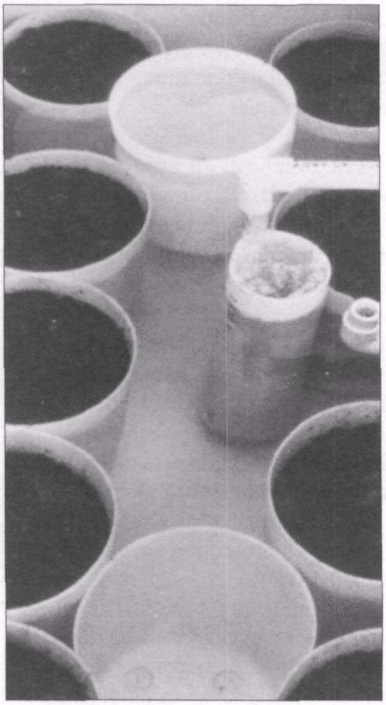
Tanks representing the test plots were set up on the fishing vessel. Perforated containers filled with contaminated cobblestone and contaminated mixed sand and gravel were placed in the tanks. Fertilizers were then applied to simulate the actual test applications. The initial microcosm results indicated that if sufficient nutrients were supplied to the microorganisms, enhanced biodegradation of the oil would occur. Because microcosms represent the test systems that best reflect field conditions, a similar response could be expected in the field.

The Culmination of the Project

By the end of September 1989, Exxon had treated 74 miles of shoreline in the largest bioremediation project ever conducted. Pontoon boats and other small craft were used to access the shoreline, and crews used airless spray pumps to apply fertilizer to the oiled beaches. This large-scale application of fertilizer was the culmination of the knowledge and experience gained during the previous months.

Winter Research

Overall, the initial findings from last summer's field and laboratory tests indicate that using nutrients to enhance biodegradation is effective and environmentally safe. To further strengthen the success of this bioremediation approach, a variety of questions still must be addressed about the fertilizers, the application methods, the potential for adverse effects, and other details. Answering these questions is critical to both the present and future application of bioremediation techniques to oil-contaminated beaches. Thus, EPA and



Researchers set up microcosms on board a fishing vessel to simulate test plots in the field and provide backup data.

During the large-scale application of fertilizers in 1989, Exxon crew members used pontoons and other small craft to apply the fertilizer to contaminated beaches.

Exxon initiated additional research in the winter following the spill to address questions remaining in the following key areas:

1. The mechanism by which the oleophilic fertilizer works.

While the summer study demonstrated that the oleophilic fertilizer effectively cleaned oiled beaches, the precise mechanism by which this fertilizer works needed further clarification. Because of the dramatic effect of this fertilizer in the field, there were concerns that it was possibly washing the oil from the surface of rocks. Laboratory studies during the winter, however, confirmed that the oleophilic fertilizer enhanced the extent and rate of oil degradation through the addition of inorganic nutrients. The fertilizer may also have enhanced biodegradation by indirectly increasing the number of oil-degrading microorganisms present in the beach sediments.

2. The optimization of fertilizer application.

The oleophilic and water-soluble fertilizers were applied in combination at Passage Cove in 1989 to provide maximal distribution of nutrients to oil-contaminated areas. Yet, there are still some questions regarding the optimal use of this combined treatment. For instance, could any reactions occur that might reduce the effectiveness of one or the other fertilizer? What application sequence should be considered for these two fertilizers? Such questions must be answered to ensure the optimal application of nutrients in the field.

3. The potential for adverse ecological effects.

During the summer field study, questions were raised concerning the potential for enhanced biodegradation to produce by-products that may be harmful to the environment. Acute and chronic tests with crustacean and fish species were conducted during the winter program that indicated no reason for concerns in this area.

4. The relationship between nutrient application and algal blooms.

Scientists are conducting mathematical studies to determine the relationship between nutrient application and enhanced algae growth. Through these studies, scientists will be able to predict what will happen to nutrients in the environment, including how the nutrients are likely to be transported and mixed, and how they will be utilized by the microorganisms. The studies will help scientists determine the effects that may be expected from any new experiments involving nutrients (and other chemicals).

5. The analytical procedure for measuring oil degradation.

Oil degradation is commonly measured by extracting oil from beach material and then analyzing its composition in the laboratory to determine the number and type of hydrocarbons present. Oil degradation has been extensively studied over the last 20 years, and scientists know that certain hydrocarbons in crude oil degrade quickly, while others are slow to degrade. Scientists frequently use some of the slower degrading hydrocarbons as "internal markers," against which the degradation rate of more quickly degrading hydrocarbons can be measured. In Alaska, however, scientists discovered that the common internal marker hydrocarbons were also rapidly degraded in some cases. This made the established procedure for measuring oil degradation of limited use, and so new analytical procedures are needed.

If scientists can develop a new internal marker technique, it will improve their ability to assess oil degradation in the field.

6. The statistical verification of field data and the modification, if necessary, of sampling procedures.

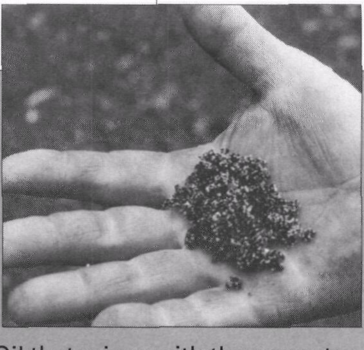
EPA is developing statistical procedures and computer programs that will allow scientists to further analyze the collected data, examine important trends, and modify sampling procedures, if necessary. Scientists are also reevaluating selected chemical and biological measurements used to study oil degradation to focus on more sensitive, less variable approaches.

Although these six studies were begun in the winter, many of them will continue throughout the summer of 1990 in conjunction with field research activities.

Activities for the Summer of 1990

A Bioremediation Monitoring Program will be conducted early in the summer of 1990. The program will supplement many of the studies from the winter research and enhance bioremediation application activities planned for the remainder of the summer. The program is designed to monitor Exxon's large-scale application of nutrients. It will be a joint undertaking by EPA, Exxon, the National Oceanic and Atmospheric Administration (NOAA), and the Alaskan Department

This clump of sand and gravel shows the consistency of oil in the summer of 1989. By the summer of 1990, much of this oil had weathered into a thicker, more glue-like consistency.



The Character of Crude in 1990

The character of crude oil found on the shorelines of Prince William Sound in 1990 will differ from the oil that was present in 1989. After an oil spill occurs in a marine environment, winds and waves help spread and disperse the oil. Some of this oil will evaporate. Oil that mixes with the seawater produces an oil-in-water emulsion (globules of oil suspended in water), commonly referred to as "mousse." Although mousse was prevalent in 1989, cleaning activities and weathering have significantly reduced its occurrence in 1990.

As time goes by, oil that has washed ashore becomes more glue-like in character and may eventually form into a hard layer of weathered oil or weathered oil mixed with fine sediments. This covering, which has the look and consistency of asphalt, is called a tarmat. Tarmats are found on some shorelines in Prince William Sound. Some of these sites will be considered for bioremediation after the tarmats are removed.

Oil may also penetrate a beach surface by seeping into the matrix of sediments or by being buried by clean sediments that have washed over the area. On some shorelines, pockets of subsurface oil may persist. Bioremediation holds great promise for cleaning up these areas in the summer of 1990.

of Environmental Conservation (ADEC). The monitoring program will focus on assessing three key effects of bioremediation:

- The amount of enhanced microbial degradation of surface and subsurface oil that can be achieved by nutrient addition.
- The potential toxicity associated with nutrient addition.
- The amount of nutrients present in the water off treated beaches.

In the spring of 1990, shoreline conditions were surveyed to determine the extent of contamination in Prince William Sound. Heavy winter storms, along with the natural processes of weathering, had decreased the amount of oil present on the shorelines. Nevertheless, oil remained on many shorelines and in the subsurfaces of some beaches. Tarmats, thick asphalt-like coverings of oil, were also scattered at sites throughout the Sound.

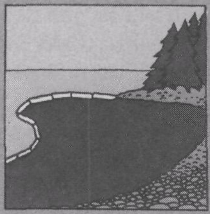
Based on these surveys, three types of beaches were chosen to serve as sites for the monitoring program: 1) a low-energy beach with surface and subsurface contamination; 2) a moderate/high-energy beach with surface and subsurface contamination; 3) a moderate/high-energy beach with subsurface contamination. Terms such as "high-energy" and "low-energy" refer to the degree of wave energy to which a beach is exposed. Over 80 percent of the coastline in Prince William Sound experiences high or moderate wave energy levels.

The selected beaches are uniformly oiled and large enough to be divided into two areas: one will be treated by fertilizer, and the other will remain untreated to serve as a reference plot. Water and sediment samples will be taken on specific days after

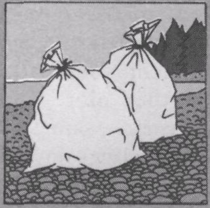
This sheltered "low-energy" beach is exposed to minimal wave action and consists of poorly sorted gravel and cobble.

Clean-up Techniques for the Summer of 1990

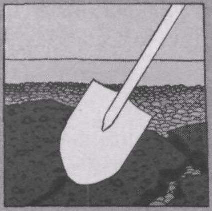
In addition to bioremediation of approximately 400 sites, five other techniques will be used to clean up the oil that persists in Prince William Sound and the Gulf of Alaska. These techniques, which were chosen because they are the least disruptive to the environment, are:



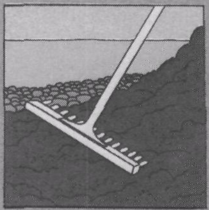
Sorbent Booms. Sorbent booms are physical barriers that intercept and absorb oil. They will be used in areas where oil sheens persist. The booms will be anchored near shore and replaced as necessary.



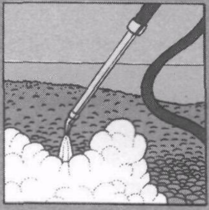
Manual Pickup. Small beach crews will use hand tools to pick up and bag oily materials. Manual pickup will help improve the aesthetic appearance of the beaches and remove potential sources of oily debris that could foul fishing gear.



Tarmat Breakup/Removal. Tarmats, thick asphalt-like coverings of oil which are slow to degrade, will be broken up with hand tools and either scattered (to facilitate natural degradation or bioremediation) or removed.



Tilling/Raking. In some areas, sediments will be raked or tilled in order to expose subsurface oil to natural degradation or bioremediation.



Spot Washing. Crews will use hand-held washing devices to remove small accumulations of oil. The water and removed oil will then be collected on the shoreline with sorbents (such as booms or "pom-poms" that are designed to absorb oil).

nutrient application and analyzed for microbial activity and the amount of nutrients and oil present. Scientists will also use time-lapse photography to characterize the visual changes in the extent of surface oil.

The Research Component

In addition to the Bioremediation Monitoring Program, EPA, Exxon, ADEC, and the University of Alaska, Fairbanks, will conduct research during the summer of 1990. Scientists from all four organizations will participate in designing and performing experiments, and in collecting and interpreting the data.

The research planned for the summer of 1990 is designed to address certain questions about the effectiveness and environmental safety of bioremediation that remain only partly answered. The research program will also address questions that will be important for future applications of bioremediation to oil-contaminated beaches.

EPA will conduct experiments to answer the following key questions:

- **How much total oil removal at a given site can be expected from bioremediation?**

Scientists will conduct an experiment to determine the rate and extent of degradation that can be anticipated when different concentrations of fertilizer are applied to contaminated beaches. Samples will be taken and analyzed in the laboratory. From these analyses, the scientists will determine what nutrient concentrations must be maintained on the beaches to remove a given amount of oil.

- **What is the best fertilizer application method for the bioremediation of subsurface oil?**

Scientists believe that oil degradation occurs at the top and/or the bottom of a subsurface oil layer (as opposed to throughout the layer). Therefore, nutrients must be consistently applied to these areas in order to enhance microbial degradation of oil. Fertilizer application will be tested on short stretches of beaches with a distinct layer of subsurface oil contamination. The sprinkler application system used in the summer of 1989 at Passage Cove will be tested on one beach plot. Bathing techniques will be tested on another plot. These techniques will work by saturating a test area with a fertilizer solution so that nutrients can seep through beach sediments into the oiled subsurface. An untreated plot will serve as a reference plot for comparison purposes.

- **Can the fertilizer application strategy for the combined use of oleophilic and granular water-soluble fertilizer be further optimized to assure maximal degradation?**

This summer, bioremediation will be tested on beaches with considerably heavier concentrations of oil than those tested last year. To optimize the effects of these fertilizers, it is important to remove as much oil as possible in the shortest timeframe. Therefore, scientists will explore applying the oleophilic and water-soluble fertilizers in different combinations using laboratory microcosms with fresh oiled beach material. Microcosms will permit scientists to determine the optimum application strategy without involving costly field operations.

- Can additional information on biodegradation activity be obtained using new experimental measurements and analyses?

To gain the most benefit from the monitoring program, as much evidence for enhanced biodegradation must be derived as possible. This means taking advantage of new analytical techniques that are not quite ready for routine use, but that can be tested on samples taken as part of the monitoring program. Several state-of-the-art techniques for measuring oil degradation will be tested.

The research data gathered during the summer of 1990 will be used to supplement findings from the monitoring program to provide comprehensive assessments on the effectiveness of bioremediation.

ORD/NETAC: Bringing Innovative Technologies to the Market

EPA and the University of Pittsburgh Trust have entered into a multi-year cooperative agreement to establish the National Environmental Technology Applications Corporation (NETAC). NETAC's purpose is to facilitate the commercialization of technologies being developed by the government and the private sector that will positively affect the nation's most pressing environmental problems. NETAC's efforts encompass encouraging new technologies with promising commercialization potential, as well as innovations aimed solely at modifying and improving existing technologies or processes.

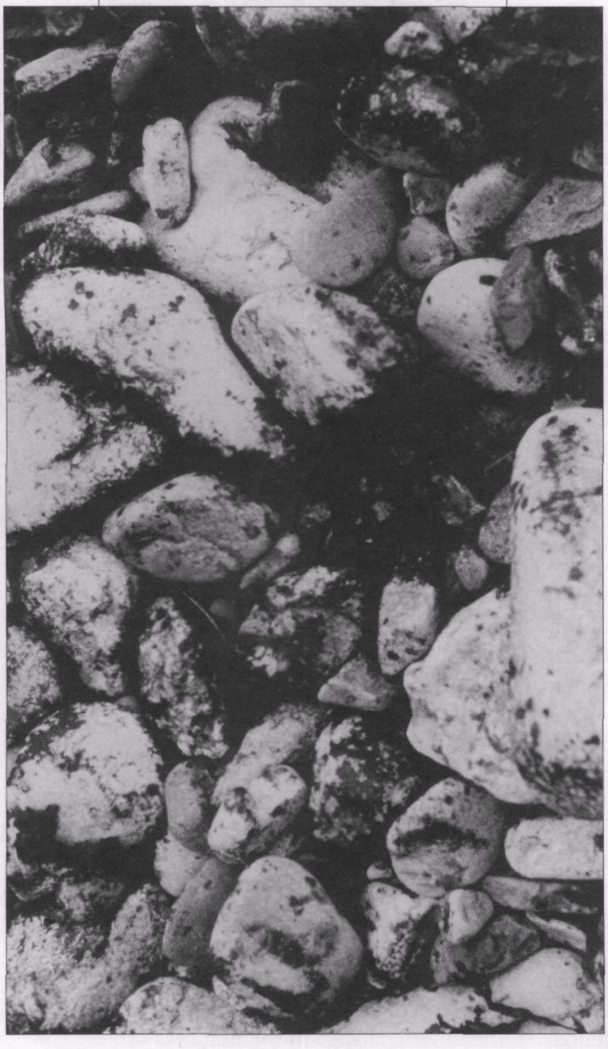
Testing New Products

ORD is also evaluating the ability of several commercial products to enhance bioremediation in Alaska. In February of 1990, ORD announced in the *Commerce Business Daily* that it was seeking organizations or companies that could offer commercial methods capable of enhancing the biodegradation of crude oil residues in Alaska. The Agency requested that these proposals be submitted to the National Environmental Technology Applications Corporation (NETAC). NETAC is an organization established through a cooperative venture between EPA and the University of Pittsburgh.

As requested by EPA, NETAC assembled a Bioremediation Products Evaluation Panel that met in March of 1990 to evaluate each of the 39 proposals submitted. The panel used detailed screening criteria to evaluate the proposals. Eleven proposals (two nutrients, one dispersant, and eight microbial cultures) were recommended for further testing, along with a protocol for performing this testing.

Ten vendors supplied products for further testing. To evaluate these products, EPA scientists placed clean beach material, weathered crude oil, seawater, and the commercial product in glass flasks. The scientists performed three different tests on these products. The tests measured the degradation of the oil, the change in the numbers of oil-degrading microorganisms, and the amount of oxygen used by microorganisms while degrading oil. (Increased oxygen consumption is often an indicator of increased microbial activity.)

The Bioremediation Products Evaluation Panel will evaluate the results of these tests. It appears likely that products having successful test results will be approved for field tests during the summer of 1990.



The Wave of the Future

Bioremediation is a technology that holds enormous promise for the future. The successful field and laboratory tests already completed indicate that bioremediation by nutrient addition offers a safe and effective way to ameliorate surface and subsurface oil. The activities planned for the summer of 1990 are expected to verify these conclusions, and further expand our knowledge.

While prevention is the best defense, it is important that technologies also be developed to combat those oil spills that do occur. For this reason, research efforts like the Alaskan Oil Spill Bioremediation Project are crucial. By understanding the science of those processes that can mitigate the potentially devastating effects of oil spills, we can help ensure the preservation of our rich and diverse natural environment.