the arctic oil & wildlife refuge

THE LAST GREAT ONSHORE OIL FIELD IN AMERICA MAY LIE BENEATH THE NATION'S LAST GREAT COASTAL WILDERNESS PRESERVE. SCIENCE CAN CLARIFY THE POTENTIAL ECONOMIC BENEFITS AND THE ECOLOGICAL RISKS OF DRILLING INTO IT

BY W. WAYT GIBBS

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Flying from Deadhorse, Alaska, west to Phillips Petroleum's new Alpine oil field, you can watch the evolution of oil development on the North Slope scroll below like a time-lapse film. At takeoff, the scene fills with the mammoth field where it all began: Prudhoe Bay, discovered in 1968 and uncorked in 1977 to send its oil down the Trans-Alaska Pipeline to the ice-free port at Valdez.

Climbing higher, the plane tracks feeder pipelines that zig westward to Kuparuk, second only to Prudhoe among the most oil-rich onshore fields yet found in North America. Like Prudhoe, Kuparuk has grown since its opening in 1981 into a scattershot of gravel well pads connected over 800 square miles by a web of roads and pipes to giant processing plants, camp buildings, vehicle lots, and dark pits full of rock and mud drilled from the deep.

To the north, the artificial islands of Northstar and Endicott appear just offshore. And as the flight descends onto the airstrip at Alpine, you fast-forward to the state of the art in petroleum engineering. Industry executives often cite this nearly roadless, 94-acre project as a model of environmentally and financially responsible oil development, proof that oil companies have learned how to coexist with delicate Arctic ecosystems.

Alpine is the newest and westernmost of the North Slope oil fields, but not for long. When its valves opened in November 2000, crude oil flowed the 50 miles back to Pump Station 1 near Deadhorse—as all oil produced on the slope must—via a new tributary to the pipeline system. By February, Alpine's production had already hit the plant's maximum output of almost 90,000 barrels a day. But the pipe to Deadhorse can carry much more.

It was built with the future in mind, and from Alpine the future of the hydrocarbon industry on the North Slope heads in three directions at once. It will continue westward, into the 23-million-acre National Petroleum Reserve–Alaska (NPR-A) on which Alpine borders. The federal government put four million acres up for lease in 1999, and exploration began last year. New fields there will deliver their oil through Alpine's pipe.

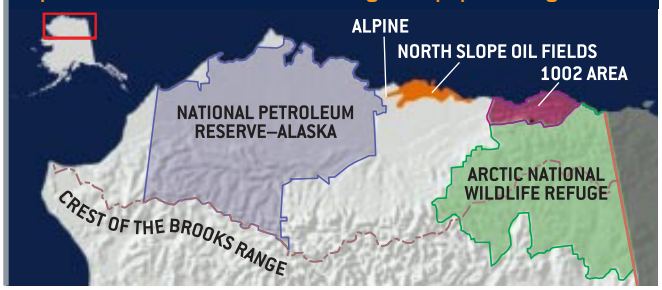
The future may lead southward as well. Soaring gas prices spurred North Slope companies last year to commit $75 million to plan a $10-billion natural gas pipeline that would open some 35 trillion cubic feet of untapped reserves to the lower American states by the end of the decade.

Beyond 2010, Phillips, BP and the other Alaskan oil producers look toward the east for new opportunities. Not 30 miles past Badami, the eastern terminus of the North Slope infrastructure, lie the coastal plain and tussock tundra of the so-called 1002 Area. It is named for the section of the Alaska National Interest Lands Conservation Act of 1980 that set aside 1.5 million acres of federal property in deference to geologists' guesses that the region entombs billions of barrels of oil and trillions of cubic feet of gas.

The same act placed the 1002 Area inside the 19-million-acre Arctic National Wildlife Refuge (ANWR), in deference to biologists' observations that the coastal plain provides a pre-

The Debate / *Oil vs. Wildlife*

- Senate bill S. 389 would open the coastal plain and foothills of the Arctic National Wildlife Refuge, the so-called 1002 Area, to oil development. A competing bill, S. 411, would designate the area as wilderness, prohibiting development.
- Geologists have used 1985 seismic data to estimate how much profitable oil and gas lie below the surface. But before any lease sale, oil companies would conduct new seismic surveys. That would leave a grid of visible scars in the vegetation of the plain but would have little or no effect on wildlife.
- Ice roads and exploration wells would follow. Fish and waterfowl may suffer if rivers and lakes are overdrained.
- A network of oil fields, processing plants and pipelines would extract the oil. A nearly roadless development may have little effect on the herd of 130,000 caribou that calves on the plain. Or it may displace the animals, affecting their nutrition, predation and birth rates, and long-term population growth.



LAURIE GRACE

ARCTIC REFUGE provides valuable calving ground for the Porcupine caribou herd. Ecologists argue that it also has intrinsic value as a "control area" against which they can compare the environmental effects of human development.

mium Arctic habitat: calving ground for the Porcupine caribou herd; nesting and staging wetlands for tundra swans and other migratory waterfowl; dens for polar bears and arctic foxes; and year-round forage for a small herd of muskoxen.

Congress thus instigated one of the longest-running environmental turf wars of the past century, and the darts have again begun to fly. On February 26, Senator Frank H. Murkowski of Alaska introduced S. 389, a bill that would open the 1002 Area to oil and gas exploration and production. The bill allows the Bureau of Land Management to restrict the activities to ensure that they "will result in no significant adverse effect on the fish and wildlife, their habitat, subsistence resources and the environment."

Can careful regulation prevent such effects? Or does even the most compact, high-tech, thoroughly monitored oil development pose an unacceptable risk to the largest American wildlife refuge remaining so close to its natural condition?

It is a mistake to ask scientists questions that force them to weigh the relative values of oil and wilderness. Some 245 biologists, not waiting to be asked, signed an open letter to President Bill Clinton last November urging him to bypass Congress and declare the area a wilderness, which would close it to development. In interviews with numerous Alaskan petroleum geologists, on the other hand, virtually all asserted that the oil industry could move in without causing more than cosmetic damage. In a fundamentally political dispute, scientists' opinions should carry no more weight than anyone else's.

Science and engineering should enter the debate over the fate of the Arctic refuge, however—not as a lobby but as a source of facts that all positions must accommodate. Thirty years of innovation has produced less disruptive ways of finding and removing the oil below the tundra. And 25 years of biology has quantified how those activities disturb the life on its surface. Before the public decides the question, it should have the clearest picture possible of what it might gain, what it might risk in the gamble—and what uncertainties are tucked into the word "might."

What Lies Beneath

AT LEAST EIGHT SEPARATE GROUPS of geologists have tried over the years to guess how much oil and gas sit below the 1002 Area in forms and places that would allow them to be recovered with current technology and at realistic prices. All eight teams relied on a single set of data from a seismic survey made in the winters of 1984 and 1985. Long rows of low-frequency microphones were set down on the snow to capture the echoes of sound-generating trucks up to a mile away as the sound waves bounced off rock layers at various depths. The string of microphones was moved, the process was repeated, and 1,450 miles of cross-sectional snapshots were taken, covering the entire 1002 Area in a rough three-by-six-mile grid.

Turning those recordings into pictures of the subsurface and then inferring from the pictures which formations hold what quantity of oil is as much an art as it is a science. "The source rocks, trap formations [that hold the oil in place] and extent of migration all must be estimated based on analogies and prior experience," explains Mark D. Myers, director of the oil and

A Model of a Modern Major Oil Field

SUBSURFACE NOT TO SCALE

REMOVING OIL from the Arctic refuge would probably require four or more Alpine-size fields. Processing plants, split into 1,500-ton modules (*1*), would be hauled on ice roads (*2*) built with water removed from nearby lakes and sprayed on the frozen tundra. Each seven-foot-thick gravel pad, accessible in summer only by air, would hold up to 60 closely spaced wellheads. Drilled by 150-foot-tall derricks or smaller coiled tubing rigs (*3*), the wells would penetrate the permafrost and then veer to run horizontally through oil pockets up to six miles away. Half or more of the wells would inject seawater or natural gas into the rock to push oil toward producing wells nearby. A central processing facility would remove water and gas from the flow of satellite fields up to 30 miles distant, then pump all the oil through a pipeline to Prudhoe Bay. The pipe could be buried under rivers and elevated five feet above the tundra to allow caribou and muskoxen to pass. Regularly spaced "loops" (*4*) would halt flow automatically if a large leak occurred. About 300 crew members would run the facility year-round.

In wintertime, large convoys of roughly 100 workers, eight to 10 sound-generating trucks (*5*) and three dozen other vehicles would crisscross the frozen tundra, shooting seismic surveys. Other teams of 100 or so would pour ice pads, drive two-million-pound mobile drill rigs onto them, then rush to complete wildcat wells (*6*) before the spring thaw in April.

ILLUSTRATION BY DAVID FIERSTEIN; PHOTOGRAPHS BY PHILLIPS ALASKA, INC. (*1, 4, 5, 6*); JUDY PATRICK (*2, 3*)

gas division of Alaska's Department of Natural Resources. Wesley K. Wallace, a geologist at the University of Alaska, Fairbanks (U.A.F.), ticks off more unknowns: "size of the formation, thickness, porosity—each has an error bar," sometimes a very large one, and even the size of the error bars is subjective.

No wonder, then, that the eight independent studies arrived at widely divergent estimates. Differences in their methods make it useless to compare them. But by all accounts, the best assessment to date is the latest one, led by Kenneth J. Bird of the U.S. Geological Survey (USGS). From 1996 to 1998 Bird and his teammates ran the old seismic data through new computer models. They gathered logs and rock samples from 41 wells drilled over the years near the borders of the refuge. They looked again at outcrops where oil-stained rock breaks through the permafrost and traveled to the adjacent mountains where some likely reservoir strata are uplifted and exposed. And they looked at the reflectance of vitrinite and the tracks made by radioactive nuclei in apatite found in the 1002 Area for clues to those minerals' temperature history, which matters because hydrocarbons turn into oil only when cooked just so.

The result is not one estimate but several, because the relevant figure is not how much oil is there but how much can be profitably recovered—and that depends in turn on the price of oil. Bird's group concluded that thorough exploration would most likely yield about seven billion barrels (bbo) of economically recoverable oil if North Slope prices remain above $24 a barrel, where they were in March. The estimate falls to about 5 bbo if oil prices slip to $18, and it plummets to a few hundred million barrels if prices drop to $12. Since 1991 the price of North Slope crude has fluctuated between $9 and $35, averaging $18 a barrel. [*More information on the range of estimates is available at www.sciam.com/2001/0501issue/0501gibbs/*]

At 7 bbo, the 1002 Area would hold about half as much profitable petroleum as Prudhoe Bay did in 1977. But as with Prudhoe, the oil could be raised only over the course of several decades, following a classic bell-shaped curve. Industry insiders say that 10 years would probably pass between a decision to open the refuge to development and the first flow into the Alaskan pipeline. Environmental-impact studies and hearings would take two years, if the history of NPR-A is a guide. Companies would then have a year or two to do more intense seismic surveys and to prepare their bids on leases. Several years of exploration typically go into each discovery—after two years of drilling in NPR-A, for example, no strikes have been announced yet. Each permanent drilling site, processing facility and pipeline extension would have to clear more environmental analyses and hearings, and each would take two to three years to build.

An analysis by the U.S. Energy Information Administration (EIA) suggests that if the USGS estimate of 7 bbo is correct, then the 1002 Area will generate fewer than 200,000 barrels a day for the first five years. The EIA also forecasts that American petroleum consumption, 19.5 million barrels a day last year, will rise to 23 million by 2010, with 66 percent of that amount imported. At its peak, probably no earlier than 2030, complete development of the coastal plain of the Arctic refuge would produce about one million barrels of oil a day. Flow from the 1002 Area would then meet something shy of 4 percent of the nation's daily demand for petroleum [*see box on next page*].

There's the Rub

PETROLEUM GEOLOGISTS know what they need to do to reduce the huge uncertainties in the USGS analysis. "The first thing a company would do is shoot a new 3-D seismic survey," Myers says. With gaps in the previous seismic data of up to six miles wide, "every prospect drilled on the slope this year would be invisible on that [1985] survey," he observes. This time "the grid would be much finer," with lines spaced about 1,100 feet apart, says Michael Faust, geoscience technology manager for Phillips in Anchorage. With new, high-resolution data, supercomputers could model the subsurface in three-dimensional detail.

The caravan of survey equipment, however, would appear much the same as before, Faust says: typically, eight vibrating and seven recording vehicles, accompanied by personnel carriers, mechanic trucks, mobile shop trucks, fuel tankers, an incinerator, plus a crew of 80 to 120 people and a camp train of 20 to 25 shipping containers on skis, pulled by several Caterpillar tractors on treads. The crew would leave in January and stay out through April, returning the next winter if necessary to cover the entire 1002 Area, 1,100 feet at a time. Each interested oil company or partnership would shoot its own complete survey, employing its own caravan.

That prospect worries Martha K. Raynolds, a U.A.F. biologist. She and Janet C. Jorgenson, a botanist with the U.S. Fish and Wildlife Service in Fairbanks, have returned six times to monitor 200 patches of tundra that were randomly chosen for study as the last seismic vehicles passed over them 17 years ago. Ten percent still showed scuffing or reduced plant cover after 10 years, and 7 percent—about 100 miles of trail—had not recovered by 1998.

The problem, they say, is the terrain. The wide, low-pressure tires of the seismic trucks leave little trace on the flat, frozen, snow-covered grasslands around Prudhoe Bay and Alpine. Rubber treads on the tractors grip well enough. But east toward ANWR, the mountains march northward and the coast withdraws. That leaves the North Slope just 20 to 30 miles within the 1002 Area to attempt its typically gentle decline from rolling foothills to stream-crazed plateau to the ice-locked Beaufort Sea. Often it fails, and the tundra piles into hummocks. Winds clear the snow from their tops, exposing the dwarf willows and the standing dead vegetation. Tires and skis crush the shrubs and compact the sedges. Rubber treads lose traction on slopes, are replaced with steel and inevitably dig in, Jorgenson says.

At breakup in May, permafrost below the compacted areas thaws early, deprived of its usual insulation. Pools form, some native plant species die, and visitors take over. Three quarters of the vegetative scars were still visible from the air a decade after the survey; many appear to be permanent. But no research suggests that the changes affect wildlife, both scientists say.

What Harm in Looking?

SEISMIC SURVEYS GENERATE CLUES, not discoveries. For petroleum geologists, truth emerges only from holes in the ground. Once the supercomputers have spit out their images, exploration teams would fan out across the frozen 1002 Area to drill wildcat wells. A mobile drill rig like the one at Alpine weighs 2.2 million pounds, so it is driven and parked on thick slabs of ice made by laying down six-inch-deep piles of ice chips and cementing them with water.

With lots of water, in fact—about a million gallons per mile of road. Around Prudhoe, tens of thousands of lakes ensure that liquid water is plentiful even when the air drops to –20 degrees Fahrenheit. Twelve years ago, however, a thorough search of the 1002 Area in April—when the ice hits its maximum thickness of seven feet—turned up only nine million gallons of liquid water sequestered in ice pockets along 237 miles of the major interior rivers. Steve Lyons, chief hydrologist for the refuge, found 255 lakes, ponds and puddles within the 1002 Area. Just 59 of those were deeper than seven feet, and only eight contained enough unfrozen water to build a mile or more of ice road. The largest basins lie in the Canning and Jago river deltas, and their bottom water is often brackish and potentially poisonous to vegetation.

Allow those few wet lakes to freeze through in winter, Lyons predicts, and next summer the waterfowl that pause in their migration to feed on invertebrates in the ponds will find fewer to eat. Draw too heavily from the spring-fed Canning, which runs free year-round, and the many kinds of fish that overwinter there may suffer, he warns.

"Water in ANWR could be a problem," says Thomas Manson, the environmental manager at Alpine, which treats and recycles its freshwater but still runs through 70,000 gallons every day. The trouble is not only quantity but also distribution: as a rule, water is drawn no farther than 10 miles from where it is needed, or else it freezes in the trucks on the way. Lyons admits that there may be technological solutions, such as a desalinization plant connected to a heated, elevated pipeline. But such measures would change the economics of the enterprise and thus the amount of oil recoverable.

Facts / *Forecasting the Flow*

- Full development of the 1002 Area would most likely produce about seven billion barrels of profitable oil, according to a 1998 analysis by the U.S. Geological Survey, but only if North Slope oil prices remain above $24 a barrel.
- If the refuge were opened to exploration this year, oil production from the area would probably begin around 2010.
- The flow of oil would rise to a peak rate around 2030 of roughly one million barrels a day—just under 4 percent of U.S. daily consumption—according to the USGS analysis. An independent estimate by Jean Laherrère of Petroconsultants in Geneva put the peak flow at just over 700,000 barrels a day, however.
- ANWR also probably holds about four trillion cubic feet of natural gas within the 1002 Area, the USGS estimates. Gas production would require construction of a new gas pipeline to connect the North Slope to the lower 48 states.

(Wild)Life Goes On

OF COURSE, IF ANY OIL is to be recovered, plants must be built. "Put four or five Alpine-size fields into ANWR with the processing facilities to support them, and you're talking about a few thousand acres of development," Myers says. "Clearly, some habitat will be damaged or destroyed. The question is: How will that modify the behavior of the animals?"

Theoretically, oil development could affect animals in many ways. Drillers no longer dump their cuttings and sewage and garbage into surface pits; these are now either burned or injected deep into wells. That greatly reduces the impact on foxes and bears. But there are other emissions. Alpine sees six to eight aircraft pass through every day, some as large as a C-130 Hercules. The scents of up to 700 workers and the noise of numerous trucks and two enormous turbines, big as the engines of a 747, constantly waft out over the tundra. A 10-foot gas flare shimmers atop a 100-foot stack. And three pipelines—two bringing seawater and diesel fuel in, one pumping crude out—fly to the horizon at just over the height of a caribou's antlers.

How the animal inhabitants of the 1002 Area would react to a collection of Alpine-style oil developments is a puzzle to which biologists have only pieces of a solution. Some wildlife does seem to have been displaced around the oil fields at Prudhoe and Kuparuk. Tundra swans, for example, tend to nest more than 650 feet from the roadways there, and caribou with calves typically hang back 2.5 miles or more.

Brad Griffith of U.A.F.'s Institute of Arctic Biology recently found two important patterns in the distribution since 1985 of the 130,000 caribou of the Porcupine herd, which arrives in the 1002 Area almost every year by June to bear and wean its young before departing for warmer climes by mid-July. The first pattern is a strong correlation of calf survival with the amount of high-protein food in the calving area. Second, caribou cows with newborns have consistently concentrated in the most rapidly greening areas (as measured by satellite) during lactation. Scott Wolfe, a graduate student of Griffith's, last year showed that the second pattern holds as well for the half of the Central Arctic herd that calves east of the Sagavanirktok River.

Across that river lie the big oil fields, and Wolfe found that from 1987 to 1995 the western half of the herd shifted its calving concentrations southward, away from the growing development and the richest forage. Ray Cameron, another Institute biologist, worries that that movement may affect the caribou numbers strongly enough to be perceptible above the normal fluctuations caused by weather, insect cycles and many other factors. It hasn't yet: at 27,000, the Central Arctic herd is five times as large as it was in 1978.

But in a 1995 study Cameron and others reported data show-

CONSTRUCTION OF OIL FIELDS similar to the new Alpine site could begin in the Arctic refuge in about six years if Congress passes a bill now before it. On each field 60 or more wells could drain oil from up to six miles away.

PHILLIPS ALASKA, INC.

ing that a 20-pound drop in the weight of the mother could lower calf survival by 20 percent and fertility by 30 percent. Cameron also tracked down radio-tagged cows and found that those that summered among the oil fields bore 23 percent fewer calves on average than their counterparts east of the river. But a critical link in this logical chain is missing: evidence that caribou, pushed off their preferred forage, don't get enough to eat.

Caribou in ANWR might suffer more than the Central Arctic herd has, because almost five times as many animals there forage in an area one fifth the size of the plain surrounding Prudhoe and Kuparuk. With fewer options, a larger fraction of the caribou cows may lose weight and bear fewer young. Oil fields could push more of them into the foothills, where calves are most likely to fall prey to eagles, wolves or bears. Griffith and his colleagues recently combined satellite imagery with caribou-calving and grizzly-bear-tracking data from the 1002 Area into a computer model. It predicts that pushing the caribou calving concentration toward the foothills would reduce annual calf survival by 14 percent on average, Griffith says.

And Fish and Wildlife Service biologist Patricia Reynolds, who monitors the 250 muskoxen that live within the 1002 Area, points out that those animals survive the brutal winters on the plain primarily by moving little and conserving stored fat. If oil workers mine gravel from the riverbanks where they stand, the muskoxen will bolt, upsetting a precariously balanced energy budget and jeopardizing their young.

On the other hand, if the drill pads are served by short airstrips rather than long networks of roads, the caribou may fear them less and suffer little displacement. Wells no longer need be directly above the reservoir, so drill pads could be placed to avoid the most nutritious cottongrass patches. Many of the muskoxen wear radio collars, so pains could be taken to avoid them.

All things considered, the wildlife would probably cope. The question is, could we? Science itself may have a vested interest in thwarting S. 389, suggests John W. Schoen, senior scientist with the Audubon Society in Anchorage. "If global climate is changing, its effects will be most magnified in northern latitudes, in places like the Arctic refuge," he argues. "How are we going to measure these subtle changes and sort out which are due to industrial development versus which are due to global climate change? One way is to protect some areas as experimental controls. The Arctic refuge would certainly serve as such a laboratory—if it remains intact."

In fact, the 1002 Area is already the centerpiece of a long and revealing experiment—a social and political experiment that may at last be approaching its conclusion. How the question is settled will reveal something about the American public's priorities, its patience, and its tolerance for risk. SA

MORE TO EXPLORE

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