Testimony before the U.S. Senate
Committee on Energy and Natural Resources

New Developments in Upstream Oil and Gas Technologies

May 10, 2011

Submitted by:
Kevin R. Banks, Director
Division of Oil and Gas
Department of Natural Resources
State of Alaska

The indigenous people of the Arctic have demonstrated a unique skill in adapting to new technologies to survive over 10,000 years. The extremes of the climate and the terrain demand only the best performance of man to succeed. Ironically, the oil and gas industry has also learned that it must bring its best tools and brightest people to the Arctic to meet the challenges of the environment.

Since the construction of the Trans-Alaska Pipeline System and the development of the Prudhoe Bay oil field in the late 1970's, the oil industry has had to invent engineering and scientific solutions to match cold, the remoteness, and the extraordinary values of the land and animals in this place. This has been a process where industry has come up with new and unique solutions applicable to only the Arctic and where industry has brought north advances in technology tested elsewhere and adapted to the special conditions of the North Slope. Everything from the civil construction of man-camps, treatment and handling of the by-products of oil development, and the installation of roads and pipelines to the high-tech science of oil exploration and development has been modified and specialized for the conditions found only in the Arctic. Even as the Inupiaq people of Alaska's North Slope have incorporated modern tools to sustain their subsistence lifestyle, so too has the oil industry adapted.

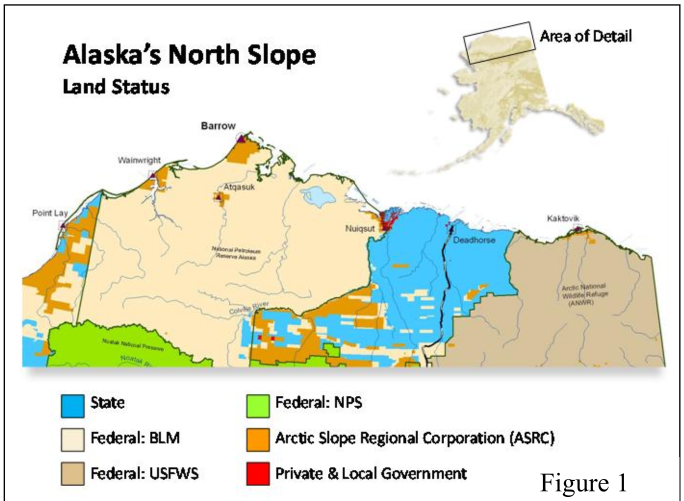


Figure 1

The North Slope represents America's toe-hold in the Arctic. Though Americans don't often think about it, Alaskans know that the US is an Arctic Nation with the same rights and concerns and aspirations as Russia, Norway, Greenland, or Canada. The North Slope of Alaska—the onshore region north of the Brooks Range—is truly vast; at nearly 150,000 square miles, an area larger than 39 states in the "Lower 48." (See Figure 1) Offshore in the Chukchi Sea north of the Bering Straits and the Beaufort Sea on Alaska's northern coast are another 65,000 square miles in just the area of the outer continental shelf (OCS) managed by the Bureau of Oceans and Energy Management, Regulation, and Enforcement (BOEMRE). Onshore the State of Alaska owns only a small share of the total acreage; the federal government is, by far, the largest landowner in the region controlling 20 million acres in the Arctic National Wildlife Refuge, 23 million acres in the National Petroleum Reserve-Alaska (NPR-A), and all of the OCS.

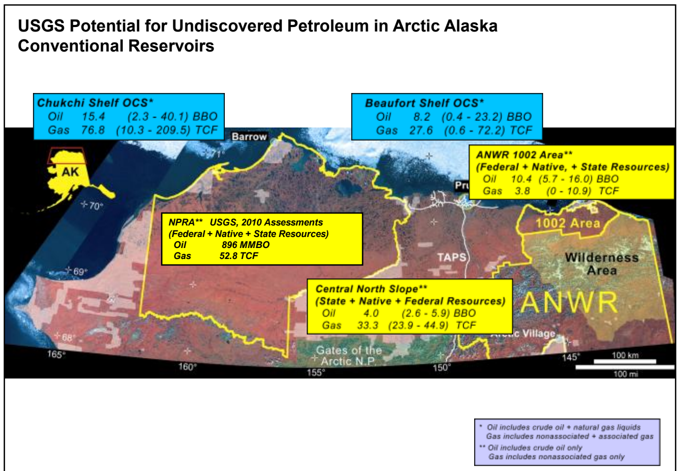


Figure 2

This region holds incredible potential for oil and gas. According to the US Geological Survey, America's Arctic ranks as number one for undiscovered oil potential and number three for gas potential for the world's conventional petroleum resources north of the Arctic Circle. Nearly 50 billion barrels of conventional undiscovered, technically recoverable oil resources and 223 trillion feet of conventional undiscovered, technically recoverable gas resources may be found in the North Slope and the Arctic OCS off Alaska's northern coast. This represents 43 percent of the nation's total oil potential and 25 percent of its gas potential.[1] Figure 2 shows that these estimates fall within a range of wide uncertainty. This range is indicated in the size of the distribution between the 5 percent and 95 percent probabilities that oil or gas resources may exceed the amounts shown. For an area like Alaska's Arctic this uncertainty should be expected. Figure 3 explains why this is so.

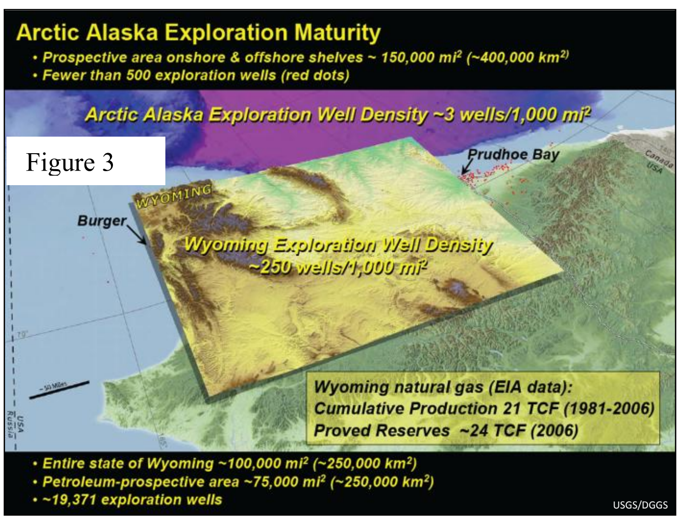


Figure 3

The North Slope has barely been explored when compared to the intensity of exploration that has already occurred throughout out the rest of the United States. If we were to place a map of Wyoming over a map of the North Slope the discovery well at Prudhoe Bay—the largest oil field in the US—would lie at the eastern boundary of Wyoming. The Burger well in the Chukchi Sea that discovered hydrocarbons there in the early 1990's would lie at Wyoming's western boundary. For reference, the 150,000 square miles of onshore area of the North Slope is twice the prospective area of Wyoming. Wyoming has seen over 19,000 wells drilled over the years or about 250 wells per 250 square miles. Only 500 exploration wells have been drilled on the North Slope; just three wells per 250 square miles. Exploration activity in America's Arctic has just begun. Over the years, as exploration has continued in places like Wyoming the assessment of undiscovered resources often continues to grow. Today's estimate of

[1] These estimates do not include the potential for undiscovered, technically recoverable unconventional resources: coalbed methane, deep-basin gas, gas hydrates (USGS mean estimate is 85 trillion cubic feet), or shale oil and gas.

remaining oil and gas reserves in Wyoming far exceeds the amount of undiscovered resources predicted years ago in spite of substantial actual production during the same time period. As exploration matures in the US Arctic the same history may be written.

We are here today to discuss advances in oil and gas exploration and production technologies, specifically improvements of seismic data acquisition and processing, advances in drilling techniques, and enhanced oil recovery. I want to describe how these and other improvements in oil and gas exploration and production operations have been deployed in the Arctic. My emphasis will be how the evolution of these technologies has through time minimized the impact of exploration and production operations on the Arctic environment.

Onshore exploration on the North Slope always occurs in the winter. The frozen tundra makes it possible to move across the land and to position drilling rigs. Winter operations have almost no impact on wildlife: polar bears move offshore, most birds and caribou have migrated south. Geophysical surveys represent the first step in exploration that contacts the land—and it is a relatively light touch. Tracked vehicles are used to spread the weight of the vehicles on the ground to avoid compaction and any scouring. Even conventional trucks can be modified with rubber track kits. Heavier loads are carried on roligons, special trucks with huge, soft tires. For those of us who remember typewriters, the wheels of a roligon look like a typewriter roller. The physical acquisition of seismic data is a labor-intensive process so the main impact on the land is the boots-on-the-ground of crews carrying geophones across the tundra. Vibroseis equipment is used whenever possible further reducing any impact to ground. The frozen tundra also provides a better medium to transmit energy into the earth.

Figure 4

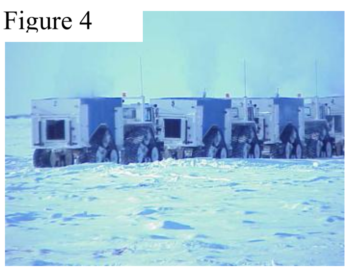


Figure 5

Figure 6

From the perspective of land use, three-dimensional seismic surveys differ from 2D seismic in the number of seismic lines laid out, the number of geophones used, and the number and placement of energy sources used. The evolution of seismic technology in the field is in the intensity of data acquisition, the sensitivity of the equipment and improvements in positioning the equipment using global positioning satellite (GPS) system. The biggest leap of seismic technology has been in the digital processing of all of the data acquired and the resultant resolution of the subsurface stratigraphy. Not more than 15 years ago, super-computers were used to manipulate seismic data. Now desktop workstations are used at a cost that many more oil companies can afford.

I've include three images to illustrate an example of the state of the art for seismic interpretation in use on the North Slope. (These are from paper written by a geoscientist from the Bureau of Land Management, US Department of the Interior. He presented this paper at joint session of the American Association of Petroleum Geologists and the Society of Petroleum Engineers held yesterday in Anchorage, Alaska. Figure 7 shows just how dramatic the resolution of 3D seismic interpretation can reveal the characteristics of the subsurface. The vertical dimension is exaggerated and what you can see in this figure is the deposition of layers of sandstones and siltstone in an underwater delta system as it crests over the continental shelf of an ancient shallow sea. Figure 8 shows more detail of how these depositions occurred in channels and at the edges of delta fans. As material flowed through these systems, the sands were transported and sorted by turbidity washing out the fines in channels and at the distal edges of the fans. In these areas are found the best reservoir rock characteristics, the more porous and permeable sandstones.

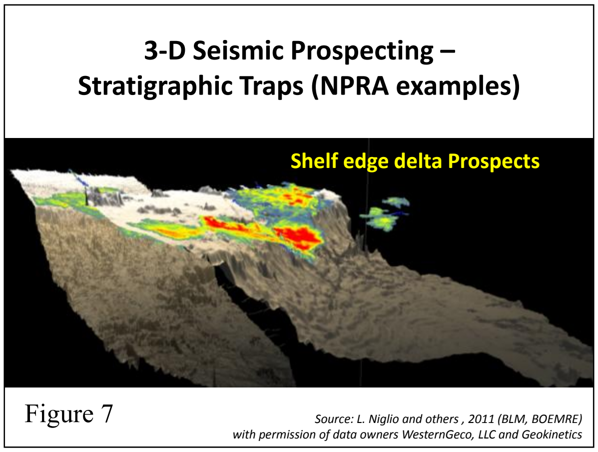


Figure 7

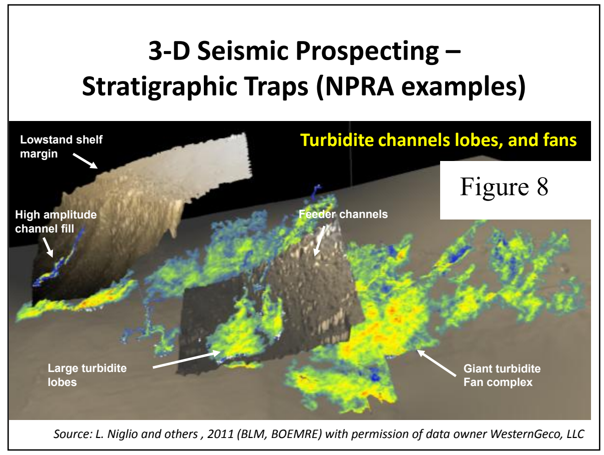


Figure 8

Figure 9 shows what the geophysicist is looking for: anomalies in the seismic reflections that can be correlated to similar anomalies detected in surveys done an area nearby where extensive drilling has already occurred. In this case, within the Alpine oil field just east of the Colville River and just outside of the NPR-A. The "Class III anomalies" shown in the bottom of this graphic are filtered out of the data and provide information of not only the rock characteristics but also the fluid properties. These same anomalies are the "bright spots" highlighted back in Figure 8.

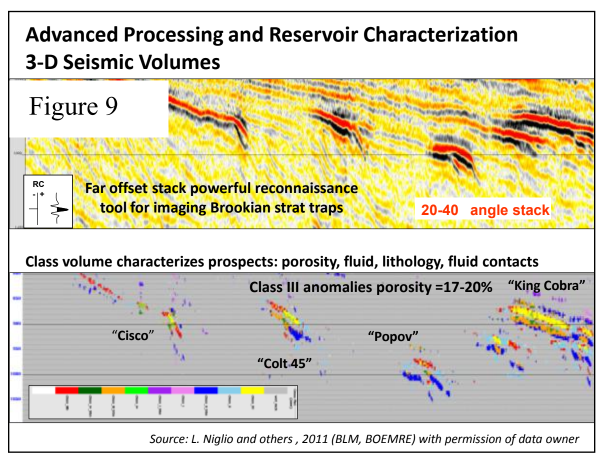


Figure 9

This kind of seismic interpretation is only possible because of the resolution and detail afforded from 3D. In this particular case drilling at Alpine provides the information from well logs and the fluids produced from the wells to identify anomalies in the seismic data where exploration drilling should occur. Because of this interpretation, the exploration program conducted in the northeast of the NPR-A was very successful in finding hydrocarbons. It also means that fewer "wildcat" exploration wells were needed to find oil and gas. Over the last twenty years, improvements in seismic technology and the application of better geological interpretation has meant that the dry hole risk has substantially declined. Better success rates for exploration wells means fewer intrusions from exploration operations on the environment.

Seismic surveys are not a replacement for actual exploration drilling. While 3D seismic surveys have fundamentally changed the exploration business, "The truth is in the drilling!" On the North Slope, onshore exploration drilling occurs only in the winter. Heavy equipment is brought out to remote sites on ice roads (Figure 10) and the drilling rigs are assembled on ice pads. Ice roads are built by hauling crushed ice to the road location to provide a substrate for trucks that spray water over the crushed ice to form a smooth hard surface. The flat terrain of the North Slope and the usually abundant water sources located there make it possible to build ice roads in most places. They are nonetheless expensive when considering that they disappear with the spring thaw. Ice roads have been used on the North Slope for decades.

Figure 10

Drilling done from ice pads

Figure 11

ConocoPhillips Alaska, Inc. 8/00

Figure 11 shows a drill rig erected on a remote ice pad in the Alpine field. The rig itself weighs several million pounds, the large structure on the left is a 100 person camp, and adjacent to the ice pad is an ice airstrip. The pad itself is at least 12 inches thick and in many cases insulation and rig mats are placed on top of the ice to protect it and distribute the heavy loads. All drilling wastes and other discharges, e.g., domestic water from the camp, are trucked away for disposal in approved injection wells. At the end of the winter season, a front-end loader will scrape the pad down to pure ice to allow the ice to melt more quickly. When the ice melts, there is no trace left of the pad.

The only visible sign of prior activity is an eight-by-eight foot well house that will remain on location only because this well is part of a field under development and will one day produce oil. If the well were to be plugged and abandoned, which would be the case for most exploration wells, the well would be cemented-in to prevent any communication among any formations penetrated by the well and the surface. The well would be cut off below grade, marked with a plaque welded on the top, and buried. Note the

Exploration well site

Figure 12

ConocoPhillips Alaska, Inc. 8/00

Tundra undisturbed by drilling

Figure 13

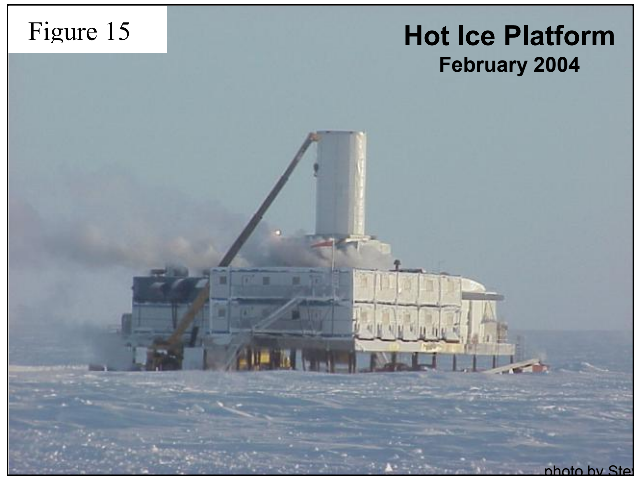
ConocoPhillips Alaska, Inc. 8/00

recovery of the vegetation around the well house illustrated in Figure 13. It is possible to explore for oil on the North Slope and leave no visible footprint.

Figures 14 and 15 are photos of the "Hot Ice" platform erected at the edge of the foothills of the Brooks Range. This is also a temporary structure and actual drilling activity only occurred during the winter. This structure was tested because it afforded a way to store the drilling rig and to stage other equipment through the summer months. This exploration concept is intended to be used in very remote sites. The length of the ice road and the time needed to build it means that the drilling season is shorter for these sites. With the rig already in place, winter drilling can begin earlier and continue longer than could be accomplished by building an ice pad.

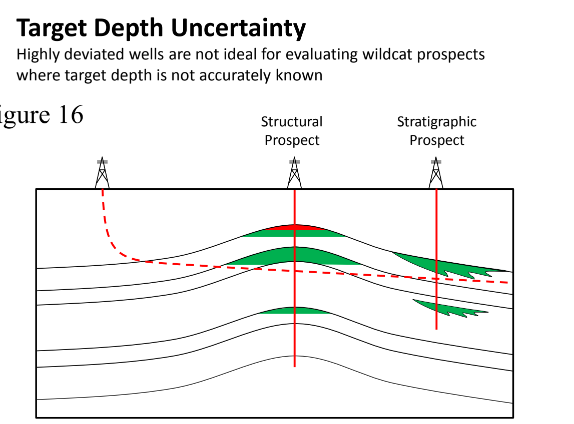
Figure 14

Figure 15



Extended reach drilling techniques have advanced tremendously in recent years and, as the technology has evolved, drillers have extensively used these techniques on the North Slope. While suitable for the production phase, vertical wells are still the best way to explore for hydrocarbons especially on the North Slope. The main advantage of a vertical exploration well can be seen in Figure 16. Even with the best 3D seismic information available, there is some uncertainty of the target depth for a wildcat objective. A highly deviated well can overshoot or undershoot the oil or gas zone whether the zone is a structural or stratigraphic trap. On the North Slope when the time to drill is constrained by the winter season, the explorer can drill a vertical well faster and with better control. A deviated well is more difficult to drill, more difficult to log successfully, and is more expensive. Once measurements are taken, e.g., true depth established and correlated to the seismic information, delineation wells drilled to assess the areal extent of the prospect can be drilled using horizontal drilling techniques. In some instances delineation wells can be drilled laterally from the same borehole of the first exploration well.

Figure 16



As extended-reach drilling technology has evolved so has the deployment of the technology on the North Slope. From a land use perspective and as a way to minimize environmental conflicts, extended reach drilling combined with improvements in well design that allows for closer well spacing—the distance between the wellheads at the surface—has been incredibly successful. The evolution of drilling on the North Slope is another example of how industry has brought to the region technologies developed elsewhere and then improved upon for the unique conditions in the Arctic. These improved technologies are then exported from the North Slope to other regions where new improvements are made and new tools are developed. Then the resulting new technology is brought back to the North Slope. Figures 17 and 18 show the twin impacts of well spacing and extended reach drilling.

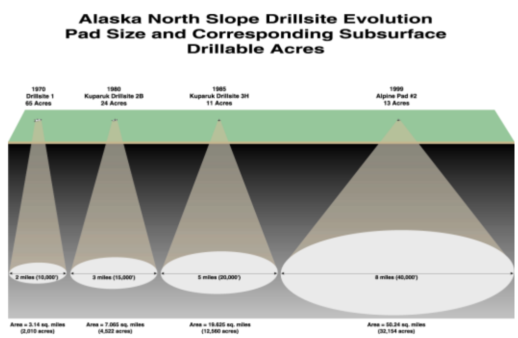


Figure 17

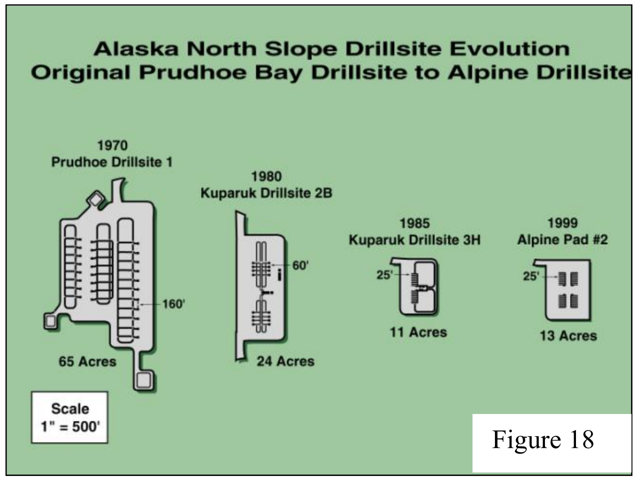


Figure 18

The first drill sites in the Prudhoe Bay field were built in the 1970's and used well spacing of about 160 feet and covered 65 acres of land to accommodate the footprint of the drilling rigs of the day. As many as 25 or 30 wells drilled in three rows from these sites could deviate to approximately one-mile from the vertical. By the time the first production wells were drilled in the Kuparuk River field in the early 1980's, improvements in rig design and drilling techniques and the materials used in the wells meant that the area of the drill sites could be reduced by more than one-half. The first drill sites in the Kuparuk River field had a well spacing of 60 feet and a 16 well drill site was just 24 acres. Wells from these first drill sites could deviate more than one-and-a-half miles from the vertical.

By the mid 1980's the technology employed in the Kuparuk River field had advance significantly. A 16 well drill site was reduced to just 11 acres and the wells could deviate by more than 2.5 miles from vertical and penetrate over 12,560 acres of the reservoir.

The Alpine field in the Colville River Delta represents the next stage in drilling advancement. From a drill site of only 13 acres, 54 wells have been drilled at a spacing of just 10 feet. The rig cantilevers over the well to avoid the wellhead of the neighboring well. The extended reach of these wells can intercept an area eight miles across and penetrate 50 square miles of the field.

In just 30 years, surface footprint requirements have been reduced from over 2 acres per well at Prudhoe Bay, to one quarter (0.24) acre per well at Alpine.

The pairs of maps shown in Figures 19-24 show what this evolution means in terms of the areal extent achieved by the changes in extended-reach drilling capabilities over the years. Wells drilled from DS-1 in Prudhoe Bay could reach only a part of the field. In Figure 19 the spider diagrams represent the areal extent of the wells and their underground trajectory. The surface footprint of the drill site is much smaller, as was shown in Figure 18. Now superimpose the extent of the spider diagram from DS-1 on the US Capitol Building (See Figure 20). Some of these wells can't reach the Washington Monument and the drill site itself would dominate the area of the Capitol Building and the surrounding neighborhood.

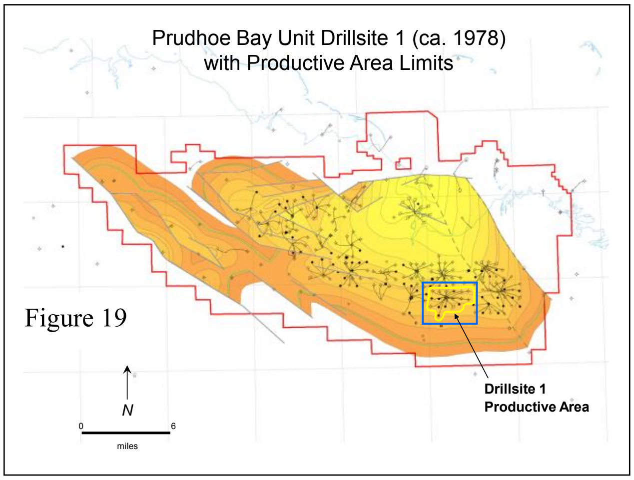


Figure 19

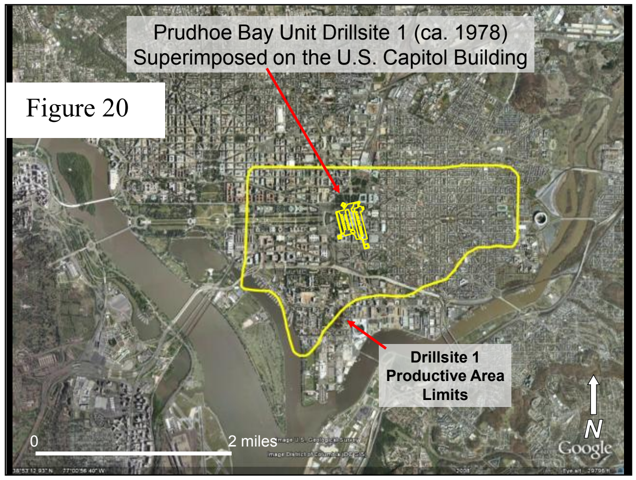


Figure 20

Improvements in drilling technology during the 1980s and early 1990s extended well reach to about 3 miles. Modular rig construction reduced the space needed between wellheads and elimination of reserve pits further reduced surface impact. Figure 21 is the spider diagram of the DM-2 drill site in the Kuparuk River field. Again the spider image shows well trajectories and how far the wells can reach. The surface impact is only a very small part of the spider diagram. Wells from DM-2 produce oil from nearly 6,400 acres (10 square miles) and the drill site has a footprint of just 12 acres. Superimpose this diagram on the US Capitol Building (Figure 22) and the wells will reach beyond Reagan National Airport and up towards Washington Hospital.

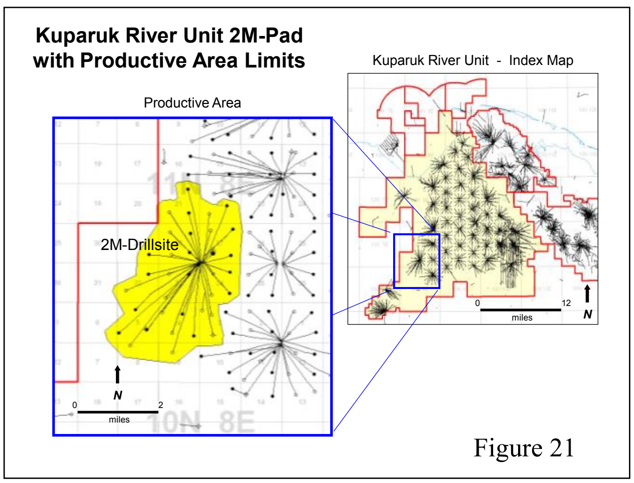


Figure 21

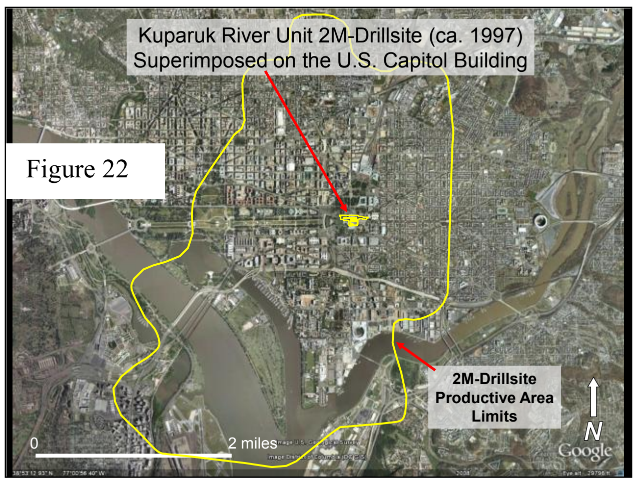


Figure 22

By 2000 extended reach drilling technology was combined with horizontal drilling techniques that had become commonplace for most all production wells on the North Slope. The Alpine field is the latest excellent example of minimizing surface impact while maximizing resource development. The spider diagram in Figure 23 shows that extended reach/horizontal wells drilled from the 11-acre CD-2 drill site in the Alpine Field can produce from about 14,200 acres (22 square miles). Some of the wells in the Alpine field can reach out 4 miles from the drill site. On a map of Washington, DC with the drill site at the Capitol Building, the wells can reach well south of the Anacostia Freeway all the way to Adams-Morgan (Figure 24).

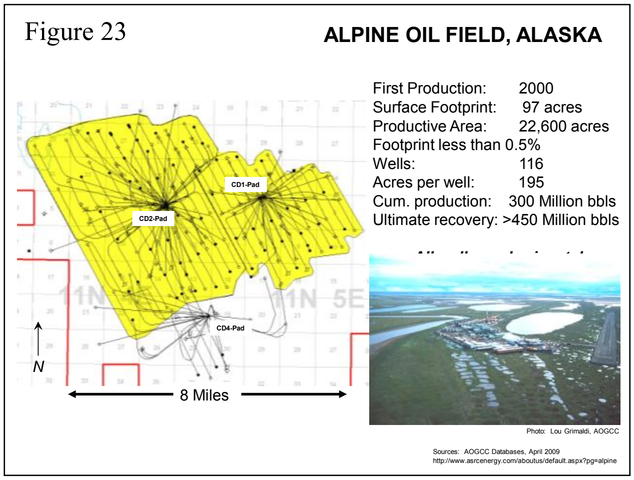


Figure 23

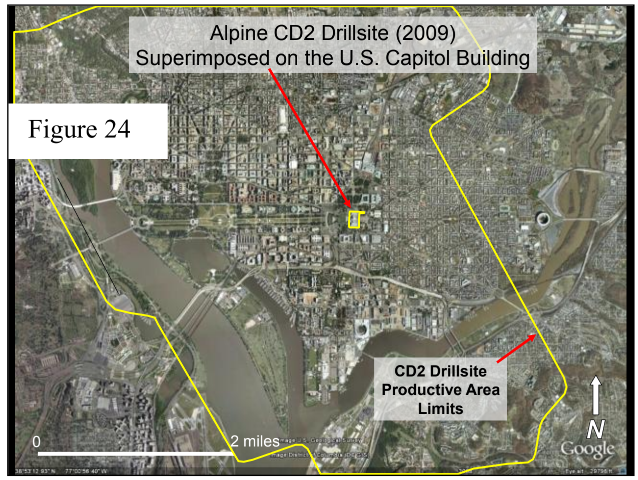


Figure 24

The Liberty project represents the next and latest phase: ultra-extended-reach drilling. Although these wells have not yet been drilled, the rig is up and undergoing final engineering and design assessments. It is likely be the largest land rig in the world. Figure 25 is a map of the proposed Liberty project. Green areas denote underground oil reservoirs. Yellow dots denote proposed drilling targets. Liberty will be developed from the existing Satellite Drilling Island (SDI) drill site originally constructed for the Endicott field. Six wells are planned that will reach up to eight miles from the island. If successfully implemented, these wells will be the longest reach wells ever drilled.

Figure 26 shows the area that could be reached by the Liberty wells if the rig was set on the site of the

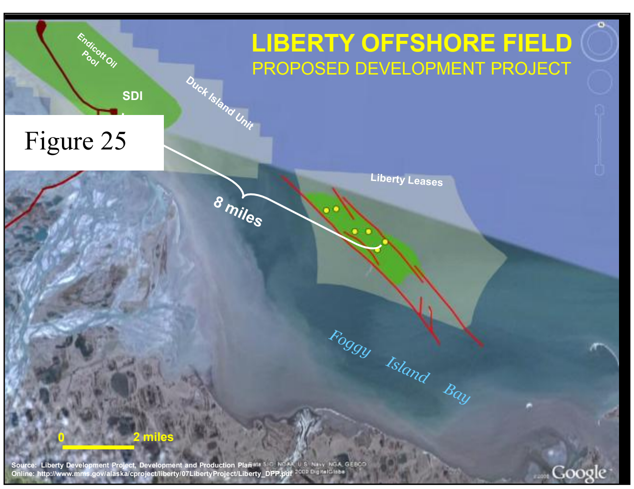


Figure 25

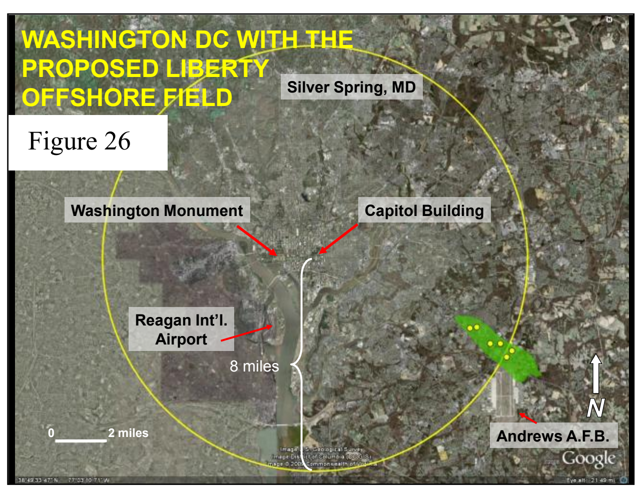


Figure 26

Capitol Building. The wells could extend out to Andrews Air Force Base in the southeast, Silver Spring in the North, and well into Fairfax County in the west. If the Prudhoe Bay field were developed today using Liberty-type drilling technology, surface impact would be greatly reduced to possibly as few as two drill pads.

The climate, the remoteness, government regulation, and undoubtedly the cost all contribute to the industry's ability to drill in the Arctic with as little impact to the land as possible. The evolution and deployment of technological improvements over the years tell a story of innovation and adaptation that is demanded of the Arctic on all who live and work there.

Epilogue: A final comment about enhanced oil recovery (EOR). Testimony by others at this hearing will provide the committee with a description of incredible and fantastic applications of physics, chemistry, and engineering to squeeze every drop of hydrocarbons out of US oil and gas fields. When applied to fields in the Lower 48, people usually think that EOR is intended to stimulate old oil and gas fields and reverse their production declines. Note that every field developed on the North Slope, including Prudhoe Bay, had an EOR plan in place before the first drop of oil was produced. Water flooding and gas injection, miscible injection, water-alternating-with-gas (WAG) were designed into the facilities as they were installed and upgraded. The optimization of these EOR projects are continually monitored using intensive surveillance tools and modeled using sophisticated dynamic simulations of the reservoirs. The Saddlerochit reservoir in the Prudhoe Bay field maybe the most well understood reservoir in the world.

The Alaska oil and gas Industry is also implementing amazing new EOR ideas. The Gas Cap Water Injection Project at the Prudhoe Bay field is such an idea. By flooding water through the gas cap, relic oil will be swept into the oil leg of the reservoir where it can be produced. Monitoring the progress of the success of this project is achieved by employing the first of its kind micro-gravity 4D survey that can remotely detect the movement of fluids through the gas cap. Pilot projects are also underway including the low salinity water injection project and polymer treatments.

A variety of artificial lift mechanisms are employed throughout the fields on the North Slope including gas lift, jet pumps, electric submersible pumps, and progressive cavity pumps. The industry has also implemented many surface gathering and processing advancements, corrosion monitoring, and equipment condition based monitoring programs.