Drilling Proposal

Non Seismic Exploration

Some non-seismic data is already available for ANWR, but it is impossible to know whether scientists will find that they need more data when the time comes to actually undertake the exploration process. Non-seismic data is essential to the exploration process because it provides a unique viewpoint that supplements seismic data. The type of non-seismic exploration techniques that would be most valuable in ANWR would be those involving potential field methods, i.e. Magnetic and Gravitational. Magnetic field methods can be done with an aerial pass of a magnetometer or on the ground using a type of magnetometer called a vertical field balance. These readings tell experts whether there is likely to be oil because there is a correlation between low magnetic readings and rocks that contain oil. Gravitational methods can also be done aerially with a gravimeter or on the ground using a more precise instrument called a gravity gradiometer. The data from gravitational methods is valuable because differences in the gravitational field indicate a difference in the density of the ground which correlates to rocks that contain oil. Both of these methods are relatively low impact because they only involve either not touching the ground at all, or setting up stations on the ground approximately 10 feet apart. In addition, as with virtually all exploration methods, the impact of non-seismic techniques is significantly lower than the impact that would be caused by drilling unnecessary wells. Consequently, we should do as much non-seismic data as is necessary to try and avoid, as much as we can, drilling these extra wells.

Seismic Exploration

Background

Seismic Exploration is basically the usage of vibrations such as sound waves and shock waves in order to map the different layers of the ground, thus enabling the operator to predict its density in varying depths. It is able to map the subsurface and to show in a 2-D, 3-D or even 4-D maps the explored region thus suggesting the locations of the oil or gas "traps" for drilling purposes.

Seismic surveying uses tools such explosives or vibroseis trucks in order to explore on land, or a tool called the airgun in order to explore offshore (ocean floor).

Here is the explanation of seismic surveying by Utah BLM Stone Cabin:

"Seismic survey methodologies are tools for analysis of geologic formations and features in the subsurface. The process consists of using a source of energy that is directed into the subsurface and then recorded back at the surface (with geophones) as the energy waves travel through the subsurface and reflect back to the surface. Various types of rock reflect the energy waves differently, and these differences are measured. Data helps show the tops and bottoms of formations, thickness, and structural configurations. It cannot identify pools of oil and gas, but rather, conditions favorable for the possible accumulation of oil and gas."

This can be found at the link:

http://www.ut.blm.gov/stonecabin/Q&As.htm

Geophone by Gisco (http://www.giscogeo.com/)

Explosives

Seismic geophones are able to collect their data from many sources that generate shock waves. Explosives method is one of those sources. By drilling small holes into the ground, approx. 12 meters deep, and packing them with 10 pounds of capped explosives (directed towards the center of earth), followed by detonation of those explosives, the geophones will be able to get sufficient data to map the are underneath the receivers. The grid lines of the explosives vary because of the different ground composure. Computer based software is often used to calculate the distance needed between the location of such explosive holes. Based on the study assembled by USGS, the grid of the explosives used in the seismic surveying that was done in ANWR 1002, was about 300 feet between the charges. Geophones were positioned in groups of 24 geophones per group while the interval between the groups was about 100-160 feet. In overall there were 120 groups in use. Due to the breaking of the ice immediately after detonation of the charges, the geologists encountered many problems, such as picking up wrong vibration data (vibration caused by the breaking and not by the blast) such secondary data affected the precision of the survey.

"Thumper" trucks, Vibroseis

30,000 pounds trucks generate vibrations underneath the ground by elevating themselves above the ground on a short pole, thus concentrating their entire weight on a platter and "shaking" for several second per location, thus sending vibrations through the ground.

The rest of the process is very similar to the explosive process because all that is left is the data

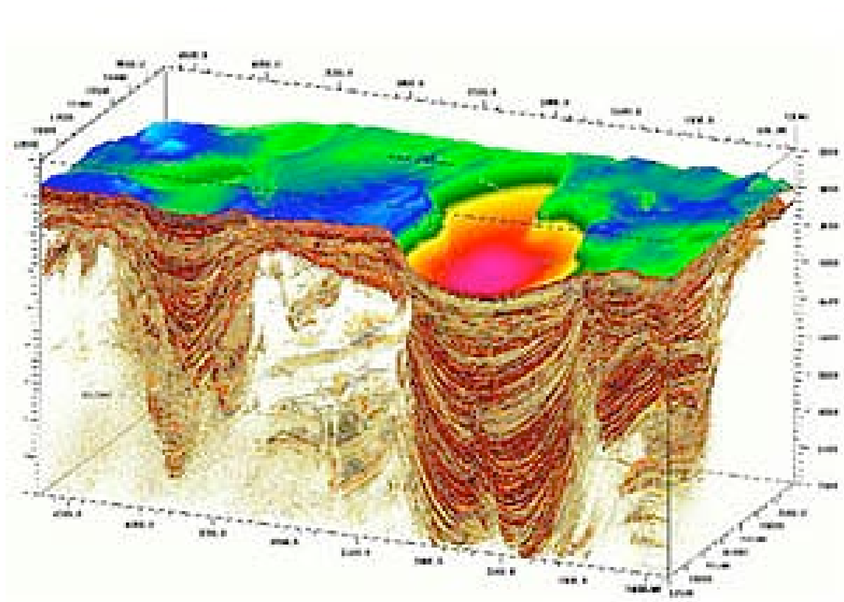
gathering phase. This process is the most precise process as it uses controlled vibrations that are spread over period of time, as oppose to the explosion vibration that is just a giant burst of energy. Those trucks are able to operate even inside major cities because the vibration they are causing is negligible due to the spread of vibration over a period of time.
This is an image of such truck operating in Utah region.

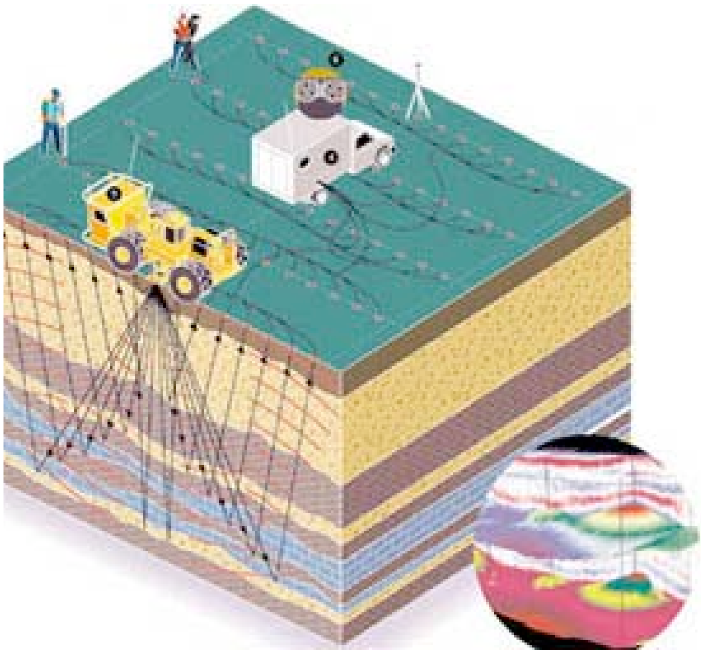
Airgun

Airgun is an excellent example of an offshore method. This exploration technique is used with assistance from a ship that actually carries all the equipment necessary to both send signal and to analyze. Such ship will carry an airgun and many receivers at greater distance that actually read the sound data as it is reflected from different rock formations and layers beneath the ocean floor. Then, just as the land surveys, the data is being processed by a computer which is later on able to generate a detailed map of several layers underneath the sea bottom.

Data Processing

The data is being received by geophones, which are relatively small devices placed on the ground. Those devices are synchronized with computer and placed on the ground using DGPS equipment (more precise than GPS, 2 meters to 30cm precision). This way the computer that analyzes the data has all the variables, the time of the vibrations, the relative distances at which the reflections are measured, and the strength (wavelength) of the vibrations. Different rocks and layers give different reflections of vibration, different changes in frequencies in the wavelength of the vibration. Using this data, gathered from the sensors, the main computer unit is able to constructed a detailed map, thus enabling it's user to analyze the map for possible oil location. It is worth mentioning that the computer is in most cases a dedicated super computer and not just a regular PC/MAC. The computer is able to generate a 3-D map of the subsurface, enabling future analysis of the region by experts and recommending a possible drill site. Another capability is a generation of 4-D map, which is a relatively new concept. Basically 4-D is a 3-D map repeated over time period. This way





you can also see any changes in the ground versus time. For example shift of layers or flow of material in reservoirs.

The truck on the left is the vibroseis truck sending vibrations as waves into the ground which are reflected of the different layer, recorder by geophones and transmitted to the data recording truck (on the right).

Evaluation of different methods and Conclusion

Based on the USGS report, the ANWR region was seismically explored in 1984-1985. Data, acquired using seismic surveying, totaling 1,451 miles is available. Furthermore, this data has already been processed and is a substantial part of the USGS report on the ANWR region. Based on those evaluations alone, it is possible that no further seismic or non-seismic surveying will be necessary in order to proceed with exploratory wells drillings. However, it is also possible that in order to suggest a more specific location of drilling further seismic exploration will be required. There are several advantages in doing at least some part of seismic exploration because of the progressed technology in the field of both data inquisition and data processing. Thus several of the seismic exploration methods should be considered.

First, the Explosives method: This method possesses much potential. Very little equipment is needed in order to drill the holes and to pack them with explosives. Although many safety measures have to be taken, it is quite possible to achieve low impact on the surface using this method. The intrusion factor of the personnel to the area of exploration is minimal. However, due to the close packed grid using this equipment it is needed to further asses the possible damage that can be caused underground.

The second possibility is the usage of Vibroseis trucks, which will be adapted to the Alaskan area. One of the methods is to replace the wheels of such trucks with tracks or thick tires, thus maximizing the spread of the weight and minimizing the pressure per point on the permafrost. Another factor is the precision of this method. Vibroseis trucks are much more precise than explosives because they deliver controlled vibration to the ground. It is even possible to send different type of waves, such as P waves (vertical) or S waves (horizontal). This way the data that will be further analyzed may yield a more precise evaluation. The trucks will be stopping for a short period of time to send the vibration and then evacuate the area, such that there is no long term damage. However, further assessment of the damage done by such tracks to the permafrost needed, as well as the assessment of the way the trucks will get into the reservoir

Depending on the quantity and quality of existing seismic data, one or both of these methods may be used in such a way that they complement eachother in order to have the least environmental impact. If a small area needs to be assessed, the explosions provide the least amount of impact. However, if the existing data is insufficient it might be necessary to use the trucks.

Production and Drill

Estimating Number of Wells

Once all of the exploration data has been gathered, the drilling locations will be selected. The goal is to minimize the number of drilling sites required and the environmental impact of each while hitting as much of the oil in the undeformed region as possible. The maximum reach of a single oil well is between three and four miles, depending on the depth of the wellbore, the depth of the kickoff point and the amount of deviation from vertical. This opens somewhere between thirty and fifty square miles. Given that the proposed drilling region is approximately 470 square miles, this require ten to fifteen production sites if the oil were evenly distributed. Since it is unlikely that the oil is evenly distributed, there will most likely be no more than around 15 drilling sites and probably no less than five.

Choosing the Drill Site

Foremost in choosing these sites is the avoidance of especially sensitive environmental areas. Drilling sites will be kept a distance to be determined by field study away from major water ways and away from the more sensitive coast in order to prevent possible significant platform spills from devastating the aquatic ecosystem. Smaller creeks and streams will not be built upon but will have activity much closer to them if it is necessary to reduce the total number of drilling sites. The site will also need to be tested for tundra integrity to ensure that the soil in the area can support the drilling platform and equipment.

Transportation of Materials

Once the winter begins, construction will start at the first sites. For the drilling companies, the winter season should be as long as possible in order to conduct the most efficient drilling and production strategy. However, primary interest concerns the well being of the 1002 ecosystem, and towards that end the drilling season will be evaluated each year to assess the drilling time which would have the least environmental impact. The three main priorities include a) a significant drop in the wildlife population as the migratory species leave, b) to have the active layer of the permafrost refreeze, and c) to have adequate snow cover to protect the tundra from moderate weight.

Sites closest to the western border of ANWR will be built first and then radiate east over the years. Since the pipeline network will use the production sites as both pumping stations and nodes, it is important to expand in this manner. The first site, assuming that oil is found, will connect to the single output line.

In order to minimize long term impact on the tundra ecosystem and to minimize the transportation burden of traditional gravel pads and the water requirements of their modern ice equivalents, the drilling and production equipment will be located on elevated platforms. Such fast assembly platforms have already been prototyped in the North Slope area and in 1002 will operate like offshore platforms in the midst of a fragile tundra sea. Such platforms would be prefabricated in modular sections and taken to the airbase outside of ANWR. In order to assemble the platforms on site, several pieces of construction equipment will be required including an auger, a crane and a forklift, as well as temporary housing until the modular sections for housing can be assembled.

These platform modules will be transported to the sites in one of two ways. The most straightforward would be by heavy-lift helicopter. Capable of loads between 7000 kg and 9000 kg, heavy-lift helicopters can carry in the modular sections or least significant pieces of them. Ground crews would arrive on site via smaller helicopter and see to the lowering of the platform modules into nearly the perfect position. The obstacle to this method of cargo transport is the arctic weather with frequently low visibility and the potential for high winds. This decision revolves around weather and flight data which is not yet fully collected or analyzed.

The alternate option, still by air, would be to use C-130 Hercules or equivalently rugged cargo planes to haul in the platform modules. This would require partial disassembly of the module sections or a more linear design capable of fitting in the fuselage. Such aircraft are capable of punching through weather more severe than likely to be found in the arctic and have a greater fuel range and weight capacity. The disadvantage is that while they can land directly on the snow covered tundra, in order to protect the underlying vegetation they might require an airstrip. It is possible that the frozen ground and the average snow cover will be sufficient to withstand the impact of landing. This could be aided by the use of larger rolligon tires. In this case no airstrip will be built and aircraft will be used instead of helicopters.

If an airstrip does need to be constructed, the standard material - gravel - is not really feasible as it a) has a high environmental impact but more importantly b) needs to be brought in by truck, requiring roads, etc. The next most common option - ice - is possible, but at an estimated one million liters per airstrip, acquiring the necessary water locally will be very difficult and transporting it seems even more preposterous. It might be possible to use some sort of synthetic material which could be applied to the ground in layers to help cushion the impact of landing aircraft. The decision of which plan to implement is contingent on future studies.

Platform Construction

The platforms, which are are supported on posts which are screwed into the ground, will need to have pilot holes drilled by a small auger; cranes and forklifts are also required to put the platform in place. This equipment may rest on a small ice pad in order to minimize damage to the tundra.

Once the platform modules arrived at the sites, the construction crews would start assembling them. Portable hydraulic jacks will lift the pieces onto sleds which snowcats can haul into the desired place. This equipment will all be brought in with the platform modules, each built to obtain the largest surface area which could reasonably be airlifted in. A drilling platform should be approximately half an acre, with an appropriate number of pylons for support. Assembly of the entire platform should take about one month. The support pylons are designed to be screwed into the ground to provide maximum support and easy assembly. Holes to get the pylons started will be bored with the backpack drills similar to those used by the seismic teams earlier. Snowcats will move equipment around the site while mobile cat mounted cranes will help with the initial construction. Once the pylons are in place, winch towers will be bolted on to hoist the platform pieces themselves into place to be bolted on. The whole assembly should erect itself accordingly with bolting and bracing so the final platform can be dissembled just as easily.

In order to prevent the permafrost from thawing due to the thermal conductivity of the platform legs, the pylons themselves will contain some type of circulating coolant, perhaps anhydrous ammonia and the radiator system employed on the Trans-Alaskan Pipeline. The first platform to be built will hold the dwelling modules for the platform workers. Supply storage will also be on this platform. The habitation platform will connect to the rising production platform by a suspended metal link bridge.

Once the production platform is in place, the drilling equipment can be bolted on. The rig must be pieced together on the platform in a space-efficient way in order to make the smallest drill pad possible. The derrick will be bolted directly to supporting pylons to give it maximum stability. Other equipment will be attached to pylons directly or to the crossbars, however the engineering specifics dictate. The diesel engines should be placed in an out of way place along with the generators, possibly insulated to cut down on noise pollution. The mud tanks should also be placed out of the way, but in such a way that the feeder pipes can be run to and from the drill string. The full list of equipment can be found here. Ideally assembly will finish only partly through the winterseason. If it takes the whole season, operations will shut down and only a small watch staff will remain at the platform. If there is significant time left in the winter, drilling will begin.

Drilling

The well must be spudded by driving a conductor pipe of approximately 12” diameter into the ground with a pile driver. The pipe will then be cleaned of rubble using a small drill head which breaks up the rubble and forces it to the surface. Once the pilot hole has been started, the drill bit of approximately 24” diameter will be lowered. Before any drilling commences, a blowout preventer must be installed in the event that the drill bit runs into a natural gas reservoir in the shallow strata.

The initial drill bit is lowered into the hole and depends on a top drive motor to drill the initial strata. Once some depth has been achieved, the drill string is raised and the down hole motor is attached directly behind the drill bit. At this point, the mud pump is connected to the drill string via a rotary hose, and the mud pump will pressurize the drilling fluid. The drilling fluid flows into the mud motor and then strikes a spiral shaft which then goes into tubular housing in such a way as to cause it to turn. As the drill goes further into the ground, drill collars are added to the drill string in order to give the drill bit the right amount of pressure drilling into the formation. The pressure needs to be just right in order to ensure the bit is contacting and drilling the formation efficiently. Each drill collar weighs approximately 6,000 pounds; it is not uncommon to have 6 drill collars to apply pressure to the drill bit. The drill bit can then be raised or lowered in order to modify the pressure put on the drill bit in order to achieve maximum drilling efficiency at all times. The drilling fluid will constantly be moving down the drill string and then up the sides of the hole, cooling and cleaning the bit and lifting the cuttings to the surface where they can be collected.

A smaller, second well will need to be drilled well away from the reservoir to be used for reinjection of well wastes. It could be drilled from a small, portable drill rig on an ice pad and take a matter of days. This is the most cost efficient and safest way to dispose of well wastes which cannot be cleaned effectively.

Once a stable formation has been reached, drilling momentarily ceases as the first casing may be cemented. Casing pipe of slightly smaller diameter than the hole is lowered into the drill site in 30 foot sections. Once the first casing section is in, cement is poured in-between the casing and the outside diameter of the drill hole, cementing the casing to the hole. It is important that the formation that the first casing is cemented into is strong enough to hold the casing, especially in the case of a blowout; if the formation is not strong enough to hold the cemented casing and a high pressure pocket is hit, the casing may shoot straight out of the hole.

Once the first casing has been cemented, drilling resumes and continues with the drill mud rotating the bit. Special mud logging equipment, attached behind the mud motor, can analyze the mud as it moves past on its way out of the hole and send that information back to the drill bit operator; it can give important notice about formation composition and pressures. Soon the cementing and casing process is repeated. After several lengths of casing has been installed, the next casing lowered will be of a slightly smaller diameter. This decreases the amount of friction exerted on the drill string. Eventually, the well bore will only be 5” in diameter, cutting down on expense and waste products.

Drilling fluids will rise out of the wellbore, carrying with it the cuttings from the formation. These will need to be cleaned out of the mud before it can be reused; this is done by a collection of mud purification and storage devices. The mud is sent through the shale shaker, which removes the larger cuttings; it is then strained through the desilter, degasser anddesander which remove the finer particles which would dramatically contribute to the deterioration of the well bit if they were recirculated in the mud. The cleaned mud is then drawn back to the mud pump, pressurized, and sent down the drill string, repeating the process.

A large diameter hole may be drilled vertically in order to penetrate all oil reservoirs vertically below the rig. That hole will then be closed by pour some cement down the hole and closing off the bottom of the hole, after the drill bit has been raised. Once the initial hole as been completed, the drill bit can be lowered again with a whipstock. This special tool fits around the drill head and forces it to deviate; how it is positioned determines the amount of deviation. In this way, the well may be explored directionally to exploit reservoirs not directly below the drill pad; the drill path may also flow horizontally through a reservoir, increasing the surface area of the pipe to the formation and allowing for faster oil production. Once that well has been fully drilled, it too will be sealed off with cement and the process will be repeated until all possible reservoirs have been tapped and exploited in an efficient manner.

Completion

Once all well bores have been drilled, coiled tubing is run into each well bore. This tubing, fairly thin, protects the casing from corrosion and is much easier to repair in the case of an accident. After each bore has been lined with coiled tubing, small explosive guns are lowered into each wellbore. These guns shoot metal slugs in all directions, perforating the tubing and shooting into the formation, perhaps even fracturing the formation. Once each charge has been set off, all wells are then opened into the main pipe and formation pressures will force the oil up the pipe. In this final stage of production, a Christmas tree (a series of valves and gauges) is installed over the producing hole which regulates the pressure of the formations and triggers safety measures if the pressure should rise outside controllable areas. The flow of the oil out of the reservoir may be controlled by the Christmas tree. A subsurface safety valve will also be installed, which remains open as long as fluid flow is normal; if the valve senses a discrepancy in the flow, it will immediately shut down. Ideally, the entire bore will be online before the end of winter. Likely it will not as there are so many sub-wells to drill in which case drilling will resume in the next winter and the platform will go into summertime hibernation. But as soon as a significant oil reserve is discovered, pipeline construction will begin. The pipeline will be constructed in sections, proceeding to each drill site after oil has been found but ideally before production has begun. Oil flow cannot begin until the pipeline is complete.

Enhanced Oil Recovery

The initial drilling process will only allow as much oil out of the well as the pressure forces out. The easiest way to stimulate a flagging pressure is by means of pumps to keep the tubing pressure less than the formation pressure. However, soon this no longer becomes feasible and at this point only 5-10% of the oil may have been recovered. Therefore secondary methods have been developed to increase the oil production from reservoirs; these usually involve flooding the reservoir with water and using the water to create pressure, driving the oil before it and up the pipe. This water flooding method may increase oil production by approximately 45% of the original oil concentration. In order to make the well extract the greatest amount of oil, tertiary (enhanced recovery methods) may be used. If the viscosity of the crude oil could be reduced, it would not need high pressures to push it up the drill pipe; therefore by adding solvents or by forcing steam into the well, the now "thinned" oil will flow up the pipe. This method may remove approximately 60% of the reservoir's initial concentration.

Pipeline

The pipeline will be routed so that one line comes into 1002 and then it branches progressively into the region to hit all of the platforms using each successive platform as a potential split. The platforms themselves will house the pumping equipment to keep the oil flowing as well as storage tanks to regulate flow. All of this will be housed on a third platform connected to the production one by another bridge. A facility to launch and retrieve "pigs" (bullet-shaped sensing devices which travels the length of the line) into the pipeline will also be erected on the platform.

The pipeline itself will be designed in a manner similar to the Trans-Alaskan Pipeline <http://www.alyeska-pipe.com/Pipelinefacts/PipelineEngineering.html> with a few small changes and one major one - the erection of a small cog rail line directly parallel to the pipeline. The pipeline and rails will be suspended from triplets of vertical pylons spaced at 20 meter intervals with two meters between them each. Between one pairing will run the crossbar supports for the pipeline while the other will have the supports for the tracks. The pipeline will be built much like TAPS with the ability to rock on the crossbars and with bumpers to soften its motion. This will also give it the ability to deal with thermal expansion. The rail lines will be cog tracks as are used in many parts of the world with high snowfall and will make it very difficult for vehicles to derail. The whole gap for the rail line is only about two meters but the structure will be designed for moving inspection and maintenance crews along the pipeline, allowing for emergency access to valves and leaks, and for regular activities like platform crew changes and supply delivery. Replacement parts for the production platforms will also be brought in this way. The trams themselves will be powered by replaceable batteries which can be changed and recharged at every platform.

Additionally, the actual construction of the pipeline will take advantage of the rail line to minimize surface impact. The rail line will be built first in pieces so that each new piece can be moved along the line to the growing end. The support pylons will be installed much like those of the platforms and the rails will be hoisted into position from those pylons. The final structure will be bolted and welded as it is much harder to inspect and maintain every bolt on the pipeline than it is for the platform. As the rail line goes in, the third pylons will be screwed into the ground and the pipeline itself will be raised into place in 10 meter sections from rail mounted cranes and pylon mounted hoists. As many of the parts as possible for the construction will be prefabricated to ensure the highest level of factory based quality control and to ease and speed assembly. When the winter ends, construction will be halted as is the norm.

In addition to transporting oil and moderate freight, the line will also carry fiber-optic cable for communicating between platforms and outside of ANWR as an alternate to satellite. Also, the pipeline will be built with a catch basin running the length under it to catch any small spills. This basin will also hold all of the sensing equipment so that should a leak occur, workers all over the region will know and be able to respond via cog rail or helicopter if weather permits.

Once the pipeline is connected to a platform, it is able to go online - assuming the drilling is complete. The production equipment (oil/water/gas/sand separators, further dehydration, water treatment, etc) will have also been set up in this time. A secondary derrick will have also drilled a single bore for reinjection of waste water, unburned gas, and rock fragments. Gas generators will also be set up to transfer electrical production from import diesel to produced natural gas. If it is not dangerous to do so, electrical lines will also be run with the pipeline (on the far side of the track) to allow drilling platforms to run off of the gas electricity of producing platforms and to provide greater electrical reliability.

Routine Maintenence

In addition to the many sensors that will be monitoring the pipeline for any discrepencies in its integrity, there will be routin visual checks of the pipeline by platform crews sent out on the rail system. They will check individual sensor calibration at valve points and assess pipeline integrity. On the platforms, on-duty mechanics will be monitoring valve and formation pressures at all times in case of a sudden change in formation pressure. This is an added measure in conjunction with the Christmas tree and subsurface valves.

Accident Cleanup

The Coastal Plain area of the Arctic National Wildlife Refuge is covered mainly by wet tundra. The high water content of this type of tundra provides some protection to the roots of the plants from crude oil spills, which tend to float in the water. Water can also slow the movement of non-water soluble substances into the soil pore spaces, and while the leaves of the plants might be killed by the spill, the roots may survive and grow during the next spring. Wet tundra is also very sensible to physical damage, but it can also recover more quickly from it than drier types of tundra do.

When treating a spill in wet tundra, the possibility of contamination of water sources should be taken into consideration, since the water in the soil might move the spilled substance. If the drainage transect the spill site, dividing the water flow may be required to treat the site. Frozen wet tundra facilitates the recovery of a spill because it prevents the substance from penetrating the ground.

The possible damages caused when responding to a spill need to be weighed against the benefits of removing additional crude oil. It has been proven that a spill of 250 barrels per acre, or 10 mm in height, recovers completely without treatment in 24 years. However, larger spills don't show the same rate of recovery.

The initial response to any spill should be to stop the spread of the substance across the tundra, to prevent wildlife injury, and to recover as much free material as possible to minimize soil penetration.

Crude oil spills:

Winter: The months when the coastal plain is covered by snow are the ones when it is easier to recover from an oil spill. The crude oil will be absorbed by the snow, making it easy to remove using hand tools or heavy equipment in rolligon tires, depending on the extent of the spill. If the crude is doesn't land directly on snow, this method can still be used by applying snow to the substance and recovering the mixture by the same method. The saturated snow should be recovered in plastic bags or disposal drums and transported to offsite facilities for treatment and/or disposal.

If the ground is frozen and the crude oil has reached the soil, it is necessary to scrape the top 1 to 3 inches of surface contamination to remove contaminated material while preserving some of the roots and stem bases of plants to allow for re-sprouting. It is first necessary to clear the area of snow using a front-end loader to expose the tundra. Then the top 1 to 3 inches of vegetation are removed and transported to waste disposal facilities.

Spring, Summer & Fall: The first measure that should be taken during a crude oil spill during the warmer months is to contain and stabilize the contaminated area using large-diameter water-filler hoses. Sand bags can also be used but may contaminate an area during storage since they can't be properly cleaned and may not be reused multiple times. Once the area is surrounded by the land barrier, fresh warm water should be used to flood the spill site. This will reduce the infiltration of oil into the root zone and the amount of oil in contact with vegetation. The floating oil can be recovered by using skimmers such as a portable rope-mop or vacuums. After the majority of the spilled substance has been removed, the surface can be flushed with commercially available surfactants to increase the ability of water to dissolve non-miscible products and reduce the adhesion of crude oil to vegetation. Using warm water at low pressure, flush towards a lined depression or trench and shored with a land barrier. The ground may be agitated while flushing using the water flow or a squeegee. The flush water should be recovered from the depression with a pump and disposed of.

Saline water spills: Saline water comes to the surface during oil production and its frequently used for enhanced recovery. Fire-fighting chemicals also contain large quantities of salt and represent the same threat to the environment.

Salt increases the osmotic potential of soil water, making it impossible for plants to absorb it. It spreads rapidly in wet tundra, covering a larger region each season and reducing plant coverage by as much as 80%. In mixed spills of crude oil and saline water, the clean up should start with the salt water since it spreads more easily and it is not biodegradable.

The immediate measures taken during a saline water spill should be to contain it using land barriers like large-diameter water-filled hoses or sandbags, and vacuuming as much salt water as possible. Then it is necessary to repeatedly flood and vacuum the spill site to dilute the salt and minimize the effects it will have on the soil. If all measures fail and the salinity of the soil is extreme, gypsum can be added to counteract the effects of the salt and salt-resistant plants can be planted to populate the area.

Mud spills: Mud spills occur from dripping mud reserve tanks and from well blowouts. During the winter months, the mud will freeze in contact with the snow and can be recovered by scrapping down to 1 or 2 inches from the soil and vacuuming the rest of the frozen substance. During the warm months, the mud spills can be treated like saline water spills and recovered by flooding and vacuuming.