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CHAPTER THREE:

OIL AND GAS OFFSHORE PRODUCTION



Planning

When exploration uncovers oil and gas fields with prospects for a good economic return, the next step is figuring out the best way to extract it. That planning period can take longer than even the exploration process. The time between the gathering of the first seismic data and the first barrel of oil is typically at least eight years — and can be as many as 20.

Some of the first things to consider are what types of platforms, pipelines and vessels are best suited to the region. Decisions must be made about how the petroleum* should be transported to onshore facilities. Questions about how and where the oil and gas will be processed and transported to market must also be resolved before any construction can begin on the production phase of the project.

Host Facilities

In offshore production, oil and gas are extracted from the wells and brought to the surface to a host facility above the ocean surface. The type of facility depends on the location, water depth, climate and the facility's size and capabilities. Environmental, safety, stakeholder and financial issues are also considered when selecting among the options.

Resisting Environmental Forces

HURRICANES

Platforms in tropical, hurricane-prone regions and areas subject to extreme storms such as the North Sea off the coast of the United Kingdom are specifically designed to resist extreme waves and winds and to minimize environmental damage. In the Gulf of Mexico, hurricanes can produce winds of 150 mph

or more and massive waves over 75 feet high, and platforms there must be able to withstand those forces over an average 30-year production life. Close monitoring of the weather allows platform crews to prepare for evacuation by halting drilling activities, securing the facility and shutting down production. The platforms are structurally reinforced for added resistance and equipped with devices such as surface controlled subsea safety valves to seal off the wells thousands of feet down. Hurricane-resistant platforms are designed to survive direct hits from these storms without significant damage.

EARTHQUAKES

Platforms in seismic zones, like Alaska's Cook Inlet, California and Russia's Sakhalin Island, are built to resist the intense ground movements caused by earthquakes. Structures



PILTUN-ASTOKHSKOYE B
A FIXED PRODUCTION PLATFORM 7.5 MILES OFF
SAKHALIN ISLAND IN 105' WATERS (2007).

in these areas are designed to have the strength to ensure no damage from earthquakes.

CURRENTS

The changing motions of tides and currents can cause severe structural stress to platforms. Tidal swings of 30 feet occur in the Cook Inlet twice daily, pushing winter ice against the platform with every cycle. Here, the platforms must be specially strengthened to resist ice impact and protect the wells.

Bottom Supported Platforms

GRAVEL ISLANDS

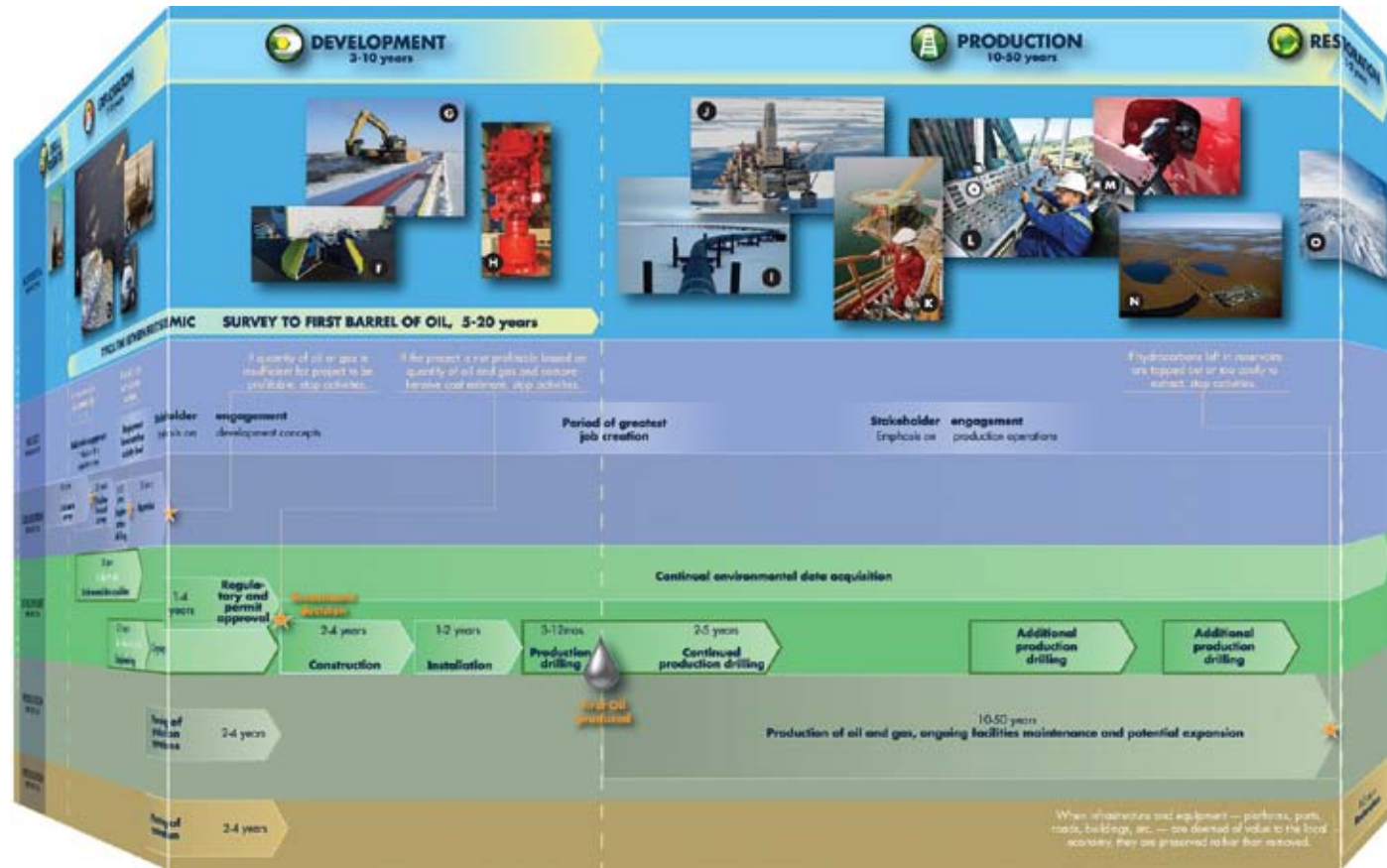
Man-made gravel islands may be used year-round in water depths of up to 50 feet and can support large drilling rigs and oil and gas production equipment. Many tons of gravel are placed on the seafloor to create the island. When production is completed,

the islands may be left to erode naturally or dredged to a depth that allows for vessel navigation. Gravel islands typically must be strengthened with concrete, rock or steel sheet piles to resist the impact of ice.

STEEL JACKET

Typical fixed steel platforms consist of large pipe legs and a tubular steel cross bracing that form a "jacket." The jacket is supported by piles driven into the seafloor to transmit wave, wind, current or ice forces into the ground. They support a deck that contains a drilling rig, the crew's living quarters and production facilities. Jackets are usually used in shallow to medium water depths and are intended for long-term use. Steel jacket platforms can operate in up to 1,400 feet of water and withstand hurricanes and winter storms. They are typically not the best solution for severe arctic areas with large ice ridges and multi-year ice.

* The terms "petroleum," "hydrocarbons" and "oil and gas" are often used interchangeably throughout this text. For definitions and distinctions, refer to the glossary at the end of this chapter.



GRAVITY-BASED STRUCTURES

These platforms take advantage of their large size and heavy mass to support large facilities in water depths of up to 1,000 feet. They can also be designed to resist severe arctic conditions, such as multi-year ice and even icebergs in shallow waters and in depths of up to around 200 feet. Gravity-based structures (GBSs) can be made of steel or concrete, and provide support for heavy drilling rigs and production equipment. They function similarly to gravel islands and jacket structures, but can be used in deeper water than gravel islands and can resist ice much better than jacket structures. They effectively act as steel or concrete islands.

COMPLIANT TOWERS

In deeper waters (over 1,000 feet), small steady waves can start to cause fatigue on fixed platform structures. The constant action of millions of wave cycles against the platform is similar to bending a paper clip back and forth until, over time, it breaks. “Compliant Tower” platforms may be used instead

for operating in depths of 1,000 to 3,000 feet.

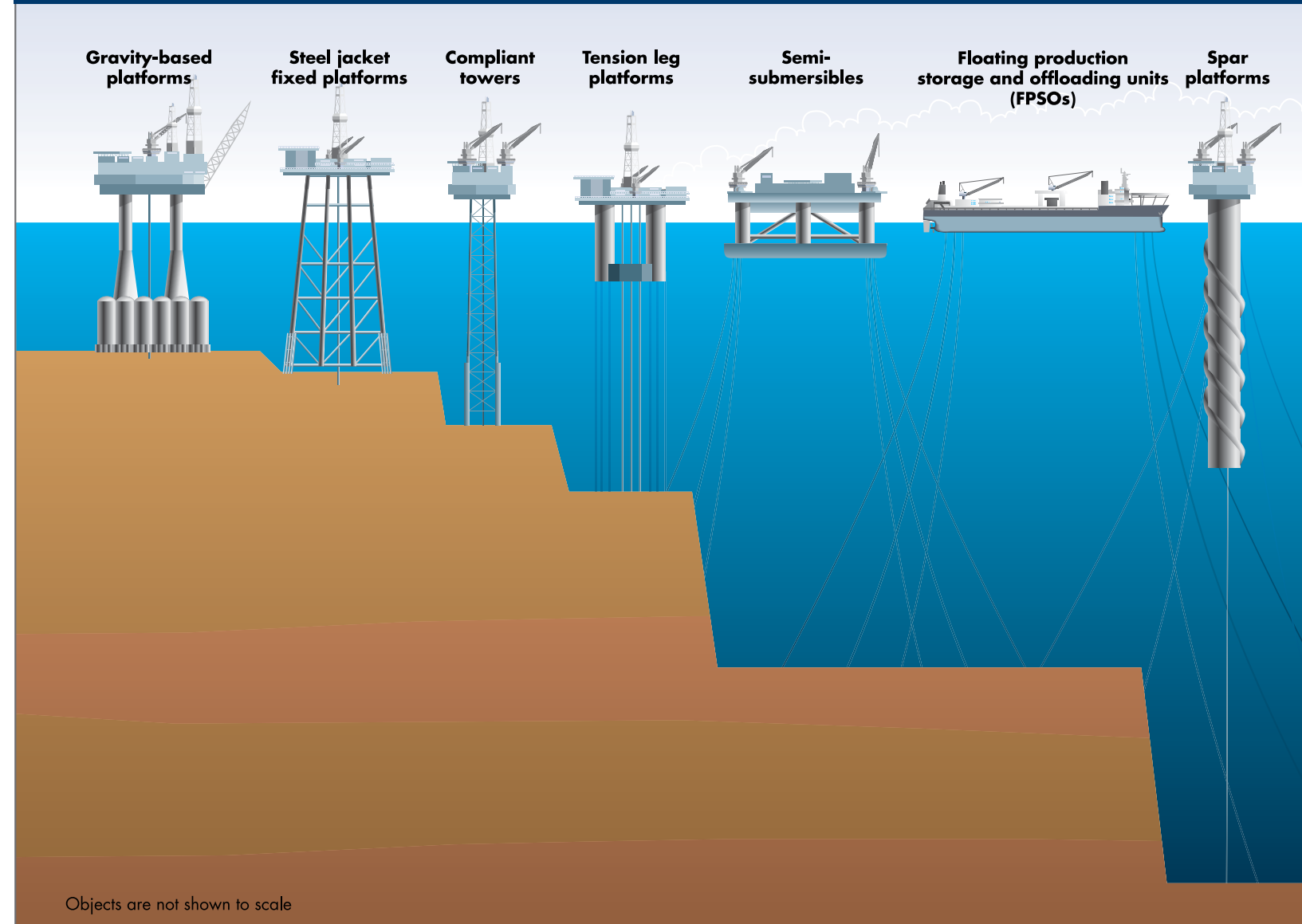
The platforms are slender and so flexible that they sway when hit with these small waves so they don’t experience the fatigue that a fixed platform would see in these great depths. The narrow, flexible towers have pile foundations and can support a conventional deck for drilling and production operations.

Floating Rigs

TENSION LEG PLATFORMS (TLPs)

These floating platforms can support a drilling rig and production facilities. The TLPs are similar to fixed platforms except they use a floating hull tethered to the seafloor by a mooring system made of tension legs. These steel “tendons” limit vertical movements from wind and sea forces and keep the TLP in position. Many TLPs are built with a four-column design that supports the deck section. Below the water, a ring of pontoons connects the columns, much like a semi-submersible drilling vessel. TLPs can be used in up to 6,000 feet of water.

PRODUCTION PLATFORMS



SEMI-SUBMERSIBLES

A semi-submersible production platform consists of a deck supported by four columns and connected underwater by four pontoons. Similar to TLPs, semi-submersibles can support living quarters and production equipment. Unlike TLPs, their floating hull uses a conventional lateral mooring system of steel cables to keep the platform in position and are connected to subsea wells via flowlines. The subsea wells are drilled by mobile offshore drilling units (see page 7) since there is typically not a drill rig on a semi-submersible production platform.

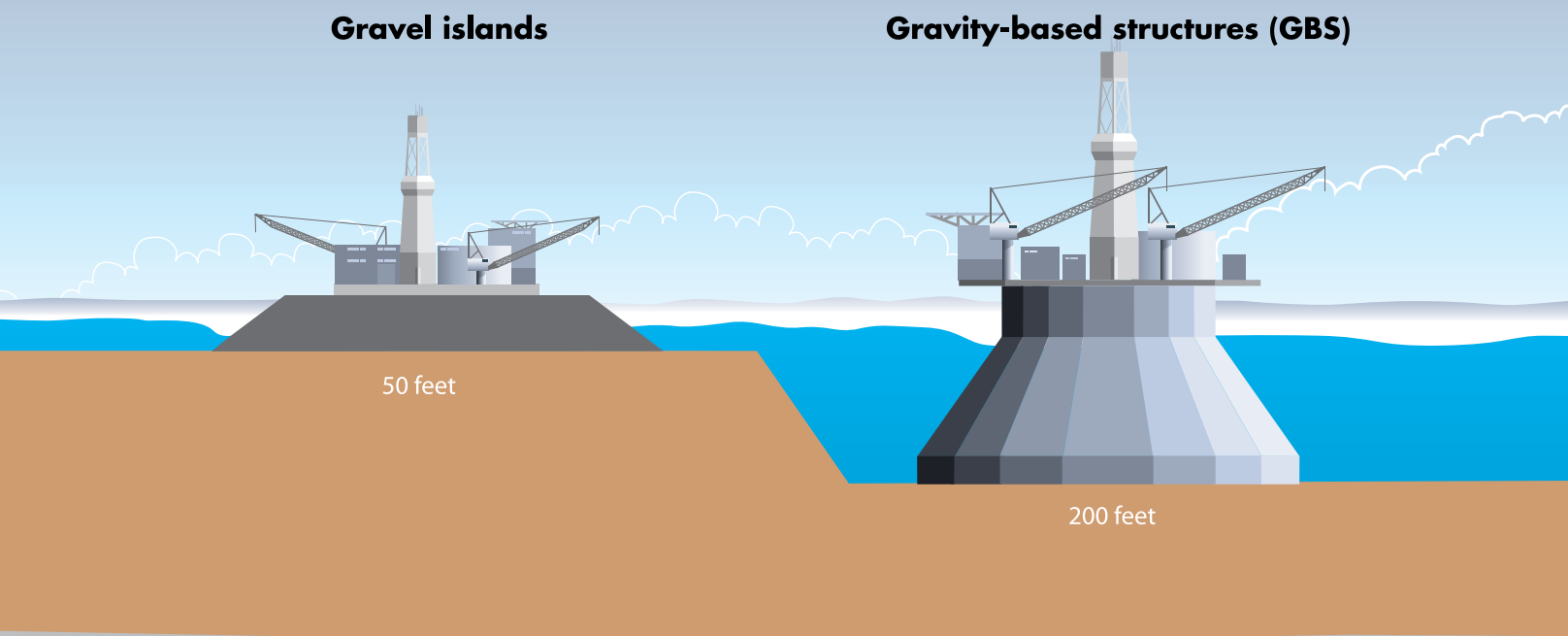
SPARS

Much like the TLP, Spars are moored to the seafloor, but with a more conventional lateral mooring anchoring system instead of tension legs. They are supported by a floating, hollow cylinder containing extra weight in the bottom, similar to a huge buoy. About 90 percent of the structure is underwater, so it has great stability in very deep waters — as much as 10,000 feet.

FPSOs

Floating production storage and offloading units (FPSOs) can operate in water depths up to 10,000

PRODUCTION SYSTEMS IN THE ARCTIC



Objects are not shown to scale.

Designing a structure to resist arctic ice requires a thorough understanding of ice forces that is gained through a combination of actual ice force measurements, ice model tests and engineering analyses. The configuration of an appropriate platform will depend on the severity of the ice at the location. In mild ice, the platform may have multiple columns. In severe ice, the platform may be composed of a single, large column. In all cases, the wells must be protected from the ice by containing them within the structure. Special arctic materials must be used to make sure that the structure can maintain its strength in the extreme cold. Foundations must be broad, contain extra “ballast” weight for stability and cut into the seafloor to resist ice loading.

PLATFORMS AND GRAVITY-BASED STRUCTURES (GBS)

The first Cook Inlet platforms in Alaska, installed by Shell, placed the wells in large diameter legs that prevented the tides from pushing sea ice into the

wells. Platforms in Russia’s Sakhalin Island use large diameter concrete legs to provide similar protection.

GRAVEL ISLANDS

Gravel islands are another option for arctic regions in shallower waters (up to about 50 feet). They are constructed with gradually sloping beaches and protective materials to resist ice.

SUBSEA WELLS

Subsea production systems typically lie directly on the seafloor. In the shallower waters of the Arctic, however, ice keels or icebergs pose the potential risk of colliding with the equipment. In these areas, the subsea equipment may be placed in a hole dredged into the seafloor so that the ice will pass over it without causing any damage. In deeper water depths, pipeline and subsea equipment may be safely placed directly on the seafloor, below the potential threat of ice keels.

feet and are best suited for milder climates or where there is limited pipeline systems to transport oil to shore. These ship-like vessels can process all of the oil or gas produced from a reservoir, separating the oil and gas and storing the oil until it can be offloaded to tankers for transportation. The storage capacity of the FPSO allows oil to be stored and then periodically offloaded to a tanker so that the tanker does not need to be on standby for long periods while waiting to receive production. The separated gas may be reinjected into a reservoir in the ground or exported to shore through a gas pipeline. Subsea wells send production to the FPSO through lines called “risers,” which are flexible enough to resist the heaving motion of the vessel above. Designs vary to allow different capabilities; some may be able to store and offload (an FSO for example) but do not process hydrocarbons. Most vessels use mooring systems connected to a “turret.” The turret is mounted to the hull and allows the vessel to rotate freely. Called “weathervaning,” this action allows the vessel’s bow always to point into the winds and currents, minimizing the impact of those forces. FPSOs are either modified existing tankers or can be newly constructed.

MOBILE OFFSHORE DRILLING UNITS

Wells are drilled from mobile offshore drilling units (MODUs) when no platform exists. MODUs are used for exploration wells and subsea production wells. They support the drilling equipment and living quarters, but have no processing equipment and can be easily moved once the drilling is done. MODUs allow the drilling of additional subsea wells into reservoirs that may be many miles away from existing platforms.

SUBSEA PRODUCTION SYSTEMS

Subsea production systems are composed of wells, manifolds and flowlines lying directly on the seafloor. Wells for semi-submersible platforms and FPSOs are subsea wells drilled from MODUs. Additionally, subsea wells can be connected to other systems, like Spars, FPSOs or platforms to extend the reach to nearby reservoirs, allowing existing platforms

to maintain production rates and reducing the need for additional platforms. The oil and gas from subsea wells flow in flowlines to processing platforms that may be from five to 100 miles away.

Drilling PRODUCTION WELLS

The earliest known oil wells were drilled in China in the fourth century and had depths of about 800 feet. Today, offshore well depths range between one half and five miles. At such depths, the Earth’s temperatures and pressures are tremendous. The pressure can be 1,000 times greater than at the surface and the temperature can reach 400 degrees F. Well designs must consider these severe conditions at the bottom of the well as well as temperatures at the surface, which can be -60 degrees F in arctic areas.

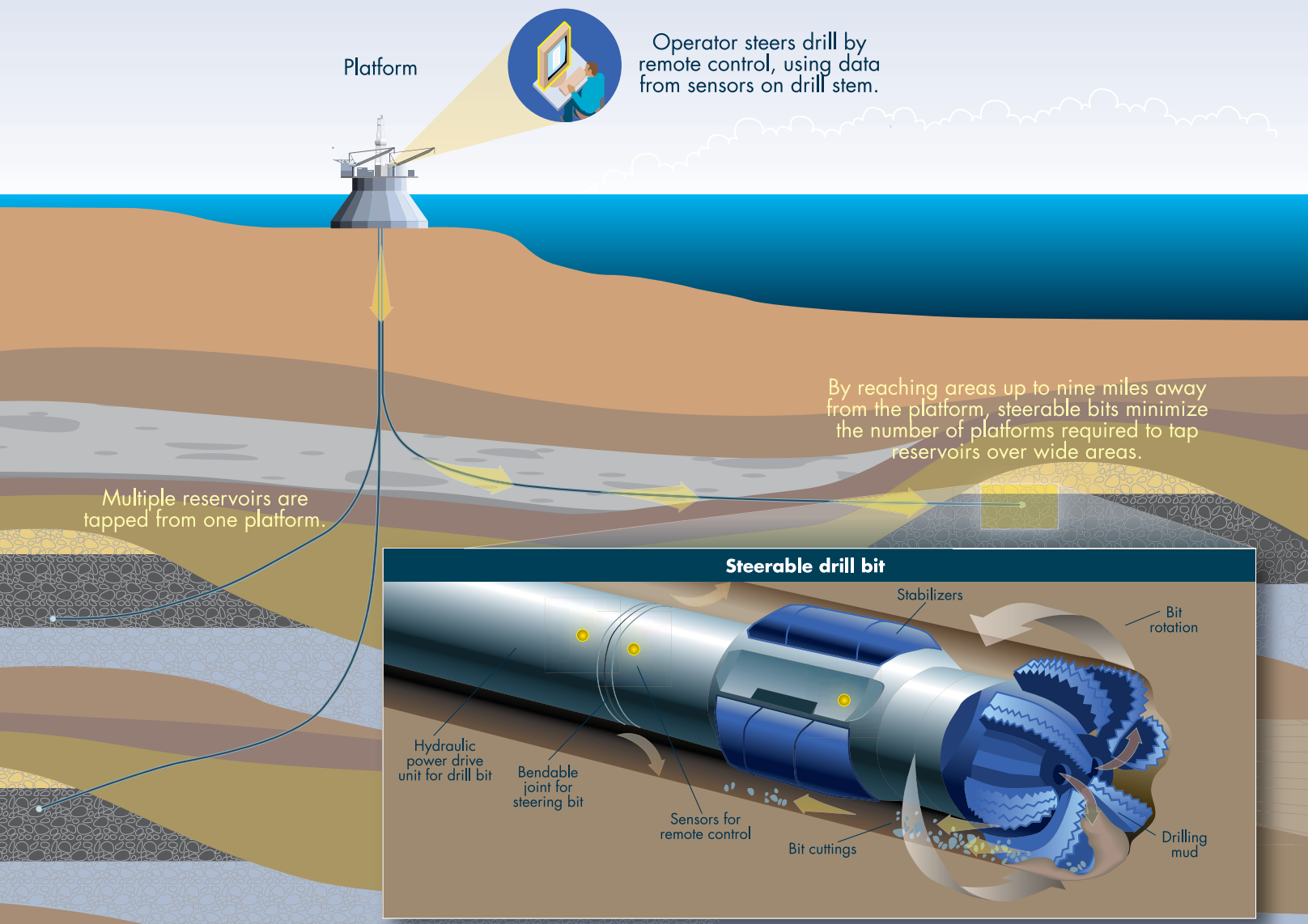


Wells are inspected and maintained to ensure safe operations throughout production, which can last as long as 50 years. As oil or gas are produced from the reservoir, it may become necessary to modify the well or drill new ones to maintain production levels. Production information gathered from the various wells, and sometimes new seismic data, will allow a better understanding of the reservoir and potentially identify additional reserves that can be produced.

DRILLING

In conventional drilling, the hole-boring drill bit is pressed against the ground and rotated. Heavier drill pipe and “drill collars” are added to provide weight on top of the bit and this enables the teeth of the bit to gouge the rock and grind it into small pieces, or cuttings. Just as with digging a hole, those rock cuttings must be brought up out of the way to allow the drill to go deeper. To achieve this, a drilling fluid called “mud” is fed down the

DIRECTIONAL DRILLING



drill pipe and into the bit, where it sprays through jets pushing the cuttings away. The mud and cuttings are forced up to the surface through a space between the outside of the drill pipe and the inside of the hole. The mud is usually a mixture of clays, additives and water that is very carefully blended to ensure the best possible performance in the existing conditions. The mud, which is also used to cool the equipment, is then filtered to clean out the rock cuttings and circulated back through the pumps and into the drill pipe once more.

DIRECTIONAL DRILLING

In the past, oil wells were drilled straight down into the Earth. One of the greatest oil-industry advances is the ability to drill horizontally. This "directional drilling" allows the operator to reach many reservoirs from one drilling rig, maximizing the amount of oil or gas that can be produced from one location. A platform will occupy only a small portion of the whole oil field, which can stretch over many square miles. Directional drilling allows wells to extend out from a central platform into multiple reservoir locations like a system of tree roots. This allows the installation of fewer platforms and means that additional reservoirs, identified in

the future, may be drilled from this central location, potentially extending the platform's productive life.

Directional drilling can also be used in places where it is not possible to position the rig directly over the reservoir. It is now possible to start drilling on one piece of land and cross under a body of water or even a city to another piece of land to reach the reservoir. One well on England's southern coast was drilled horizontally underneath a village all the way to an offshore field to preserve the area's natural beauty.

A motor on the rig called a "top drive" or a "rotary table" is usually used to rotate the drill pipe and drill bit. In directional drilling, the bit initially digs straight down and then it is turned a few degrees at a time to follow a designated path. In some cases, instead of rotating the pipe from the surface, a "downhole mud motor" is attached to the bottom of the pipe and the bit alone is rotated by the force of the circulating mud. Directional drilling techniques are so accurate that targets of less than a few feet wide can be hit, even from distances of several miles.

DERRICK AND HOISTING

Managing all this heavy work from above is a block-and-tackle system hanging from a tall mast erected on the platform. That "derrick" is the most recognizable structure in the industry and can tower more than 200 feet in the air. The hoisting system controls the weight of the drill pipe on the bit, and raises the drill pipe in and out of the hole.



CASING

When a well is started, or "spudded," sometimes a guide base of metal pipe or "conductor" is set into the seabed. This positions the drill bit, prevents the

hole from caving in, and acts as a foundation or support for the rest of the well. Extra sections of drill pipe are attached to lengthen the "drill string" to allow the well to be drilled deeper. At certain intervals, due to changes in rock strength or pressure, the well must be protected by additional metal pipes called "casing" that line the inside of the well and are sealed in with cement. Conventional drilling starts with a large diameter hole at the Earth's surface that gradually gets smaller as each metal tube must pass through the previous one. This typically looks like an extended telescope or car antenna, only on a larger scale. Today we are developing expandable tubes or casings that are narrow enough to pass through the initial casing but can then expand to match the diameter of the first, wider casing. The ability to maintain the same diameter hole from top to bottom means we can tap reserves conventional means cannot reach. The technology also allows us to drill narrower wells, but recover the same amount of hydrocarbons that would normally require larger wells.

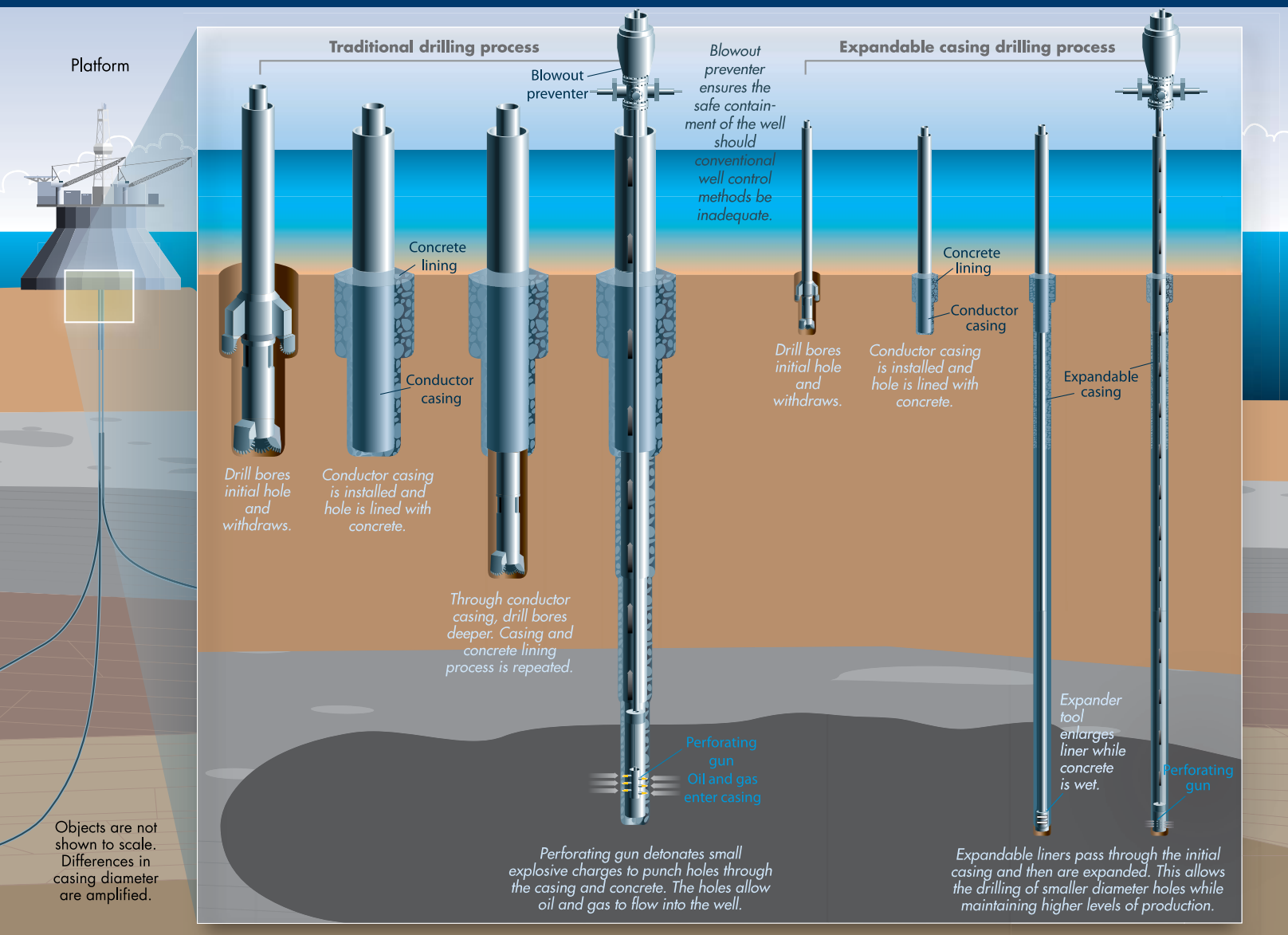
WELL COMPLETION

Once the hole is drilled into the reservoir and the final string of casing is cemented in place, tubing is inserted in the casing to bring the oil and gas to the surface. The tubing serves several purposes; it protects the casing from corrosion and is easier to replace than the casing if it does get damaged. The tubing can be equipped with devices to control and monitor the hydrocarbon flow and to stop flow completely in emergency situations. The special valves and fittings that control hydrocarbon flow and measure things like pressure and volume, called a "Christmas Tree," may either be placed above the surface of the water or on the seafloor at the top of the well.

DRILLING SAFELY

A key safety mechanism called a "blowout preventer" is installed on the top of the casing, or "wellhead," while drilling. Under normal drilling conditions, hydrocarbons are prevented from flowing out of the reservoir by the weight of the drilling mud, which counterbalances the reservoir pressure. If for some

WELL CASING

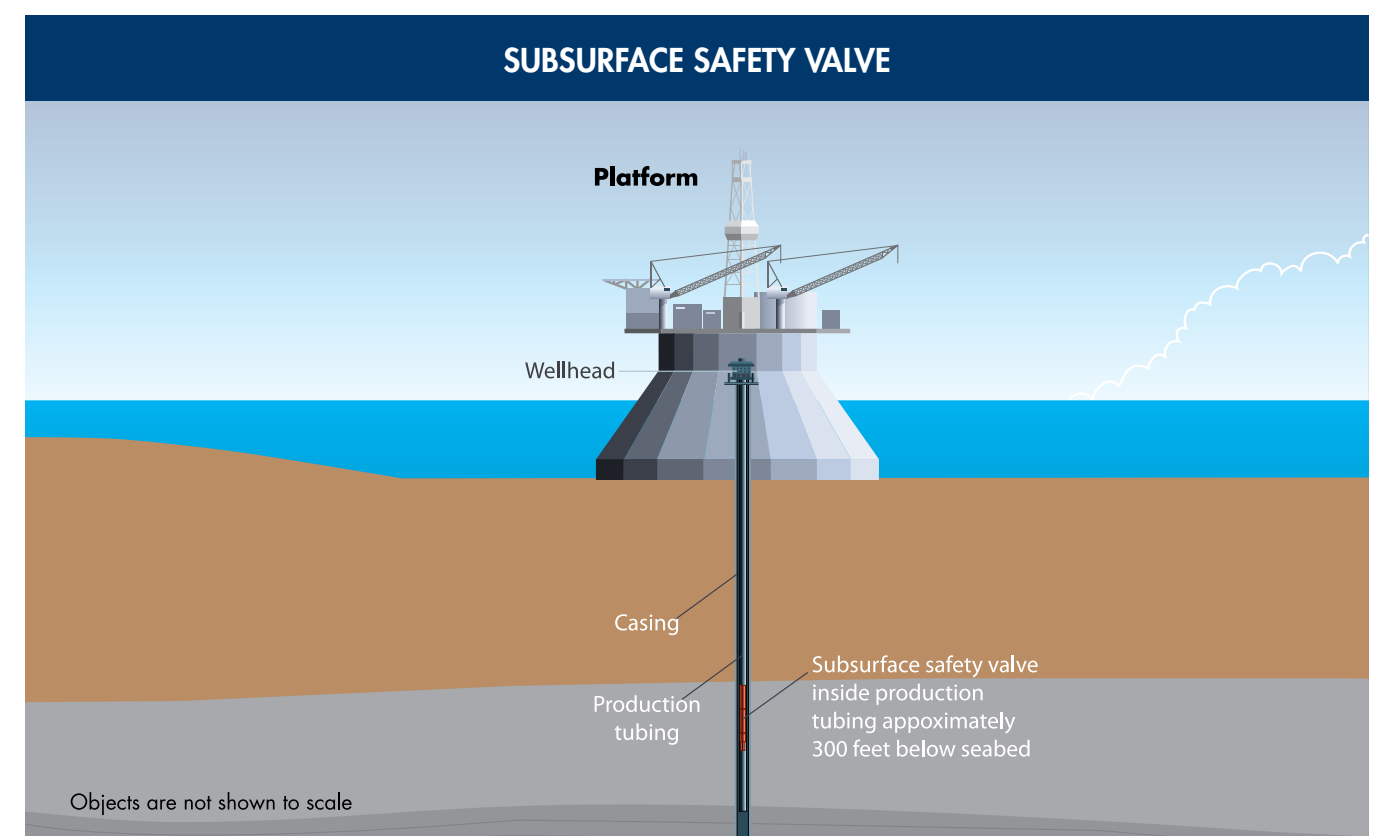


reason this balance is lost, the blowout preventer ensures the safe containment and flow of any pressurized fluids that might otherwise erupt and cause an uncontrolled release of hydrocarbons. Gone are the days of those “gushers” — the fountains of oil that once shot into the skies from the wooden derricks of yesteryear when blowout preventers were not available or commonly used.

PETROLEUM VARIETIES AND PRODUCTS

Crude oil is a liquid that comes from reservoirs below the Earth’s surface. The term “crude” is used because the liquid has yet to be processed or refined into consumer products. The refining process

eventually yields products such as gasoline, jet fuel, heating oil, butane, propane, diesel and asphalt. Crude oil is composed of molecules containing carbon and hydrogen atoms. Natural gas, water, sediment and other impurities are usually mixed with the oil and gas as it comes out of the ground and must be removed prior to transporting it to market. Crude oil runs the gamut from heavy molasses-type mixtures to fluids similar to cooking oils. How easily an oil flows has a direct impact on the design of the gathering and processing system.



Subsurface safety valves are located in all well bores approximately 300 feet below the seafloor that will automatically close to isolate the reservoir and prevent the oil and gas from escaping into the environment.

Production

EXTRACTION

The oil, water and gas sometimes travel from the reservoir to the surface under their own pressure (natural drive). If reservoir pressures are low, however, artificial lift is employed. Artificial lift can be in the form of in-well or seafloor pumps and is sometimes accompanied with in-well heating and/or gas lift systems. Some reservoirs contain heavy oils that require artificial lift. The cold temperatures in deepwater or in the Arctic also play a role in how well the oil flows. Sometimes water or produced gas is injected into the reservoir to maintain pressure and force oil toward the production wells.

PROCESSING

Once at the surface, production from the well is sent to a separator to be divided into its base components — oil, gas and water. The oil is dehydrated in a bulk oil treater before being sent to storage. It is then exported via a crude oil pipeline or a shuttle tanker to a refinery. The gas is also dehydrated before it is compressed and exported by pipeline. In some cases, injection wells are drilled to store gas safely in a reservoir for potential production in the future. The produced water is cleaned to required levels and then, depending on the location, may be discharged overboard, pumped into a disposal well or injected into the reservoir as a pressurizing system for further oil recovery.

PRODUCTION DRILLING BASICS

Shale shakers, centrifuges and/or hydro-cyclones clean the drilling mud by removing cuttings. Pumps recycle mud down the drill string.

Hydro-cyclone

Centrifuge

Shale shaker

Derrick

Blowout preventer

Production platform

Clean mud

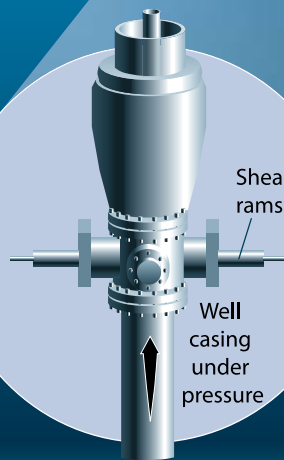
Mud pump

Clean mud pumped back to drill bit

Used mud and cuttings pumped out to be cleaned

Blowout preventer (BOP)

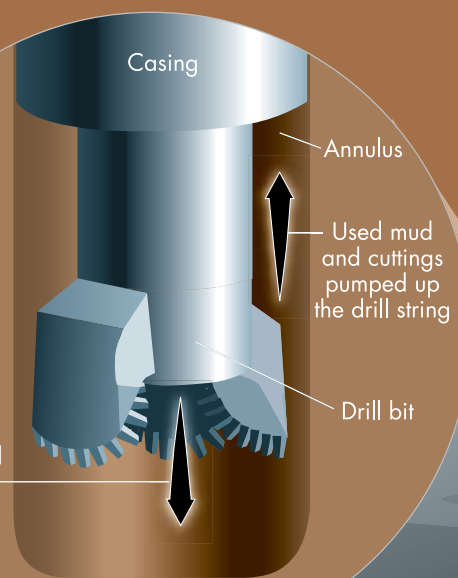
A key safety mechanism called a "blowout preventer" is installed above the wellhead while drilling. Normally, hydrocarbons are prevented from flowing out of the reservoir by the weight of the drilling mud, which counterbalances the reservoir pressure. If this balance is lost, the blowout preventer halts the flow of any fluids that might cause an uncontrolled release of hydrocarbons.



Shear rams

Well casing under pressure

Drilling mud is mixed on the rig and pumped down the drill string where it lubricates the drill bit and washes away rock cuttings. The used mud returns to the deck where cuttings are removed, allowing the cleaned mud to be recycled down the drill string.



Casing

Annulus

Used mud and cuttings pumped up the drill string

Drill bit

Clean mud

Used mud flows under pressure from the drill bit to the top in the Annulus — the space in the casing next to the drill string.

Drill bit

SAFE OPERATIONS — LIVING AND WORKING OFFSHORE

The crew size on an offshore platform can range from 10-15 for small, near-shore facilities, to as many as 150-200 members for larger operations. The living quarters include a cafeteria-type kitchen, recreation and exercise rooms, medical facilities, laundry rooms, maintenance shops, warehouses and laboratories. The operations are continuous and require coverage by day and night crews, who live on the platform during their entire time offshore. Typically one crew works on the platform for a 14-day stretch, while another enjoys their 14 days off at their homes, many pursuing side jobs or hobbies.

Extensive fire and safety systems are installed throughout the platform, including equipment that automatically shuts down oil and gas production in the event of an emergency. Every crewmember on the platform is authorized to shut down the platform should they detect an unsafe condition. The shut down system is required to halt all production within 45 seconds. Valves are used to isolate the various systems and minimize environmental impact should any system problem be identified. Subsurface safety valves are located in all well bores approximately 300 feet below the seafloor that will automatically close to isolate the reservoir and prevent the oil and gas from escaping into the environment. Should evacuation be necessary, the crew has a number of options ranging from helicopters, boats, survival capsules and life rafts. In arctic regions, specialized vehicles that can travel across ice or water are provided to carry the crew to safety.

Objects are not shown to scale



Glossary

Casing – steel pipe placed in an oil or gas well to prevent the wall of the hole from caving in, to prevent movement of fluids from one formation to another and to aid in well control.

Christmas Tree – the control valves, pressure gauges, and chokes assembled at the top of a well to control flow of oil and/or gas after the well has been drilled and completed.

Derrick – a tapered mast of open steel framework used in drilling to support the drill string and other equipment.

Directional Drilling – the deviation of a well hole from a vertical drilling angle. The method allows the operator to reach many reservoirs from one drilling rig, maximizing the amount of oil or gas that can be produced from one location.

Gravel Island – a man-made construction of gravel used as a platform to support drilling rigs and oil and gas production equipment.

Hydrocarbons – organic chemical compounds of hydrogen and carbon atoms forming the basis of all petroleum products. They may exist as gases, liquids or solids. An example of each is methane, hexane and asphalt. For this document the terms “hydrocarbons,” “petroleum” and “oil and gas” are interchangeable.

MODU – Mobile Offshore Drilling Unit often used in conjunction with semi-submersibles and FPSOs, which do not have drilling rigs.

Petroleum – a substance occurring naturally in the earth in solid, liquid, or gaseous state and composed mainly of mixtures of chemical compounds of carbon and hydrogen, with or without other nonmetallic elements such as sulfur, oxygen and nitrogen. In some cases, especially in the measurement of oil and gas, petroleum refers only to oil – a liquid hydrocarbon – and does not include natural gas or gas liquids such as propane and butane. For this document the terms “hydrocarbons,” “petroleum” and “oil and gas” are interchangeable.

Platform – the structure that supports production and drilling operations. The types of offshore platforms can be either floating or fixed, depending on the location, water depth, climate and the facility’s size.

Rig – the drilling equipment used to drill the well that can either be installed on a platform or a MODU.

Spud – to begin operations on a well.

Well Completion – the process of preparing a well for the production of oil and gas in which one or more flow paths for hydrocarbons are established between the reservoir and the surface.

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Shell in Alaska

TO FIND AND DEVELOP COMMERCIAL
HYDROCARBON RESOURCES IN THE CHUKCHI
AND BEAUFORT OUTER CONTINENTAL SHELF.
TO SUPPORT COMMUNITIES WHERE WE
OPERATE IN BENEFITING FROM ANY POTENTIAL
OFFSHORE ACTIVITIES ECONOMICALLY
AND SOCIALLY. TO RESPECT THE WAY OF
LIFE OF THE RESIDENTS OF ALASKA.