Understanding Tight Oil

Canadian Society for Unconventional Resources

INFORMATION ABOUT CANADA'S EMERGING ENERGY RESOURCES

What is Tight Oil?

Crude oil, also known as petroleum or fossil fuel, is found in some rock formations deep below the earth's surface. Crude oil forms the foundation for the petroleum industry and is relied upon for fuels as well as feed stocks for the petrochemical industry.

Oil is commonly defined as either heavy or medium-to-light grade dependent on the density of the hydrocarbon and its ability to flow. Heavy oil generally refers to crude oil that is too viscous for pipeline transport without dilution, or oil that is mined in the oil sands in Northern Alberta. Conventional oil, which is referred to as light or medium in grade, is found in reservoir rocks which have enough permeability (the ability for a fluid to move through a rock formation) to allow the oil to flow to a vertical or horizontal well.

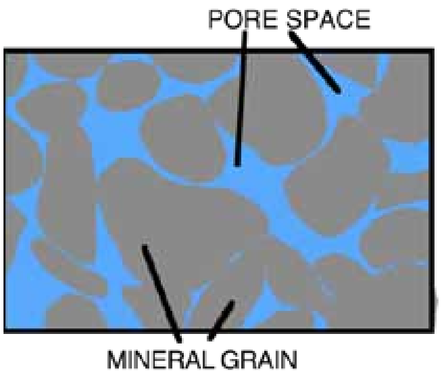
This information booklet discusses light to medium crude oil and does not address heavy crude oil.

Tight oil is conventional oil that is found within reservoirs with very low permeability. The oil contained within these reservoir rocks typically will not flow to the wellbore at economic rates without assistance from technologically advanced drilling and completion processes. Commonly, horizontal drilling coupled with multi-stage fracturing is used to access these difficult to produce reservoirs.

	Low-Permeability Reservoir	High-Permeability Reservoir
Medium to light oil	**Tight Oil** Horizontal Drilling Stimulation	**Conventional Oil** Vertical Drilling
Heavy Oil	**Immature Oil** **"Oil Shale"** Mining	**Heavy Oil** **Bitumen - Oil Sands** SAGD/Mining

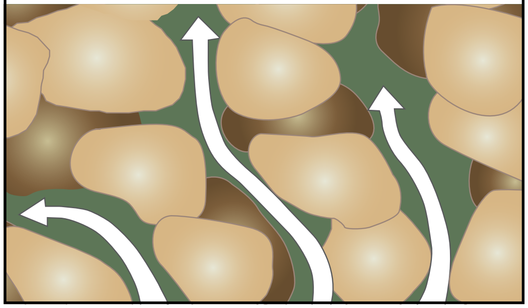
How is the Oil Stored and Released from the Rock?

Oil is trapped within the open spaces in the rock (called porosity). This porosity may be in the form of the small spaces between grains in a sandstone or as small, open vugs, or cavities, within carbonates (limestone or dolomite type rocks). For the reservoir to flow oil to a wellbore, the rock must have some form of permeability either in interconnected pathways between pore spaces or in natural fractures found in the rock. The percentage of pore volume, or void space, within the rock is generally less than 30% and in tight oil reservoirs is commonly less than 10%. The amount of oil stored within a reservoir is directly related to the porosity of the reservoir and other geological characteristics.



Source: Wisconsin Geological and Natural History Survey

Connected pores provide pathways for fluid flow



Source: Blue Ridge Group Inc and University of Texas

Example of a core sample. Typically 12 inches in length and 8 inches in diameter. The pitted surface represents visible pore space.

Source: Kocurek Industries

What kind of Oil is Produced from a Tight Oil Reservoir?

Crude oil has a number of characteristics or properties that allow it to be classified into different types. One of the main properties of oil is its density. The higher the density, the more resistant it is to flowing in the reservoir. A measure of a fluid's resistance to flow is termed viscosity. Most tight oil produced is of the medium to light variety, with a lower viscosity.

Why Explore for and Produce Tight Oil?

The world has relied extensively on the production of oil for many years and continues to be dependent on it as the primary source of transportation fuels. As countries continue to produce oil resources, there is a natural decline in production as the easy to access resources are depleted. Essentially, our conventional oil and gas resources are like low hanging fruit; produced utilizing existing technology such as vertical wells and small scale stimulations.

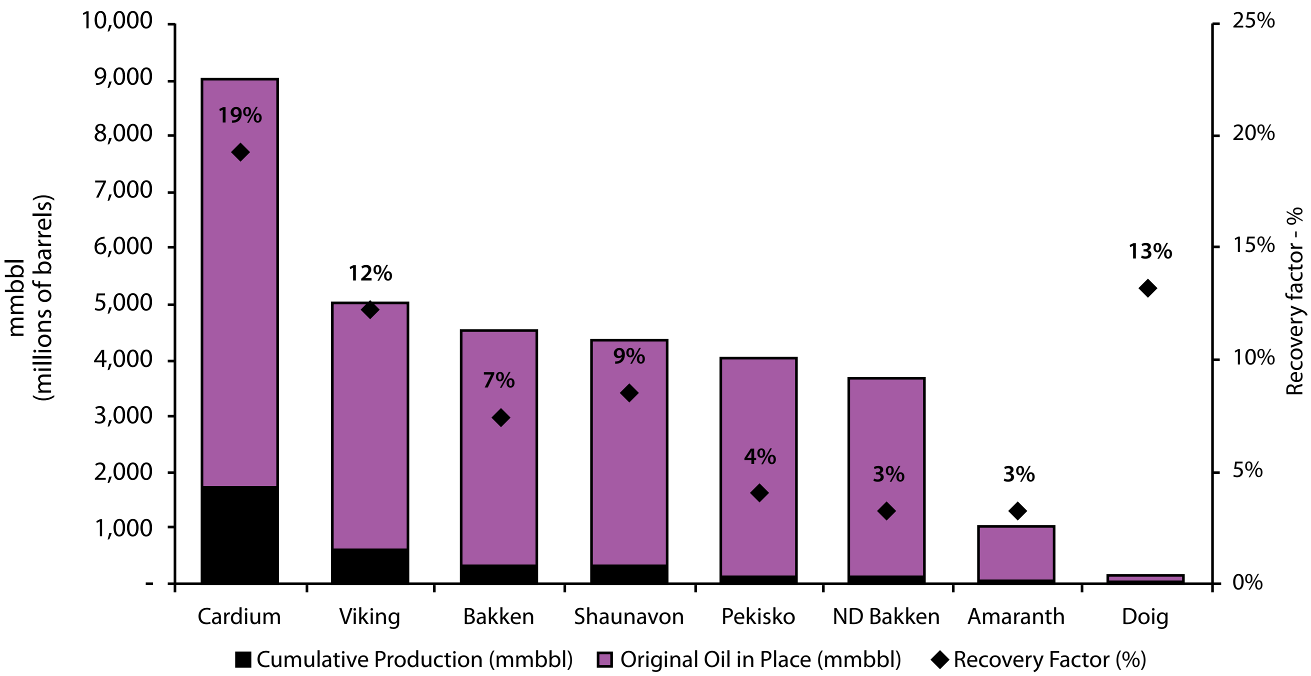
Extensive oil and gas resources are known to be present in tight oil reservoirs, however, they require additional technology to enable them to be produced. Tight oil is of high quality but commonly found in regions where reservoir properties inhibit production using conventional drilling and completion techniques. The oil itself requires very little refinement and, in many cases, existing surface infrastructure can often be utilized, reducing both surface impact and capital investment.

Conventional Oil resources are the low hanging fruit

Unconventional Oil resources are large but require advanced technology to harvest

What is the Size of the Resource?

Industry and Government often report the Original Oil in Place (OOIP) resource for regions or geological formations that are believed to have, or are proven to contain, oil and gas potential. The OOIP is simply the amount of oil that is trapped within the reservoir underground. This amount is often many times larger than the actual amount of oil industry is capable of recovering. As the chart below illustrates, the potential for additional recovery from existing oil and gas fields is significant if new technologies can be applied. With the application of horizontal drilling and multi-stage hydraulic fracturing, industry is successfully extracting additional oil from these reservoirs.



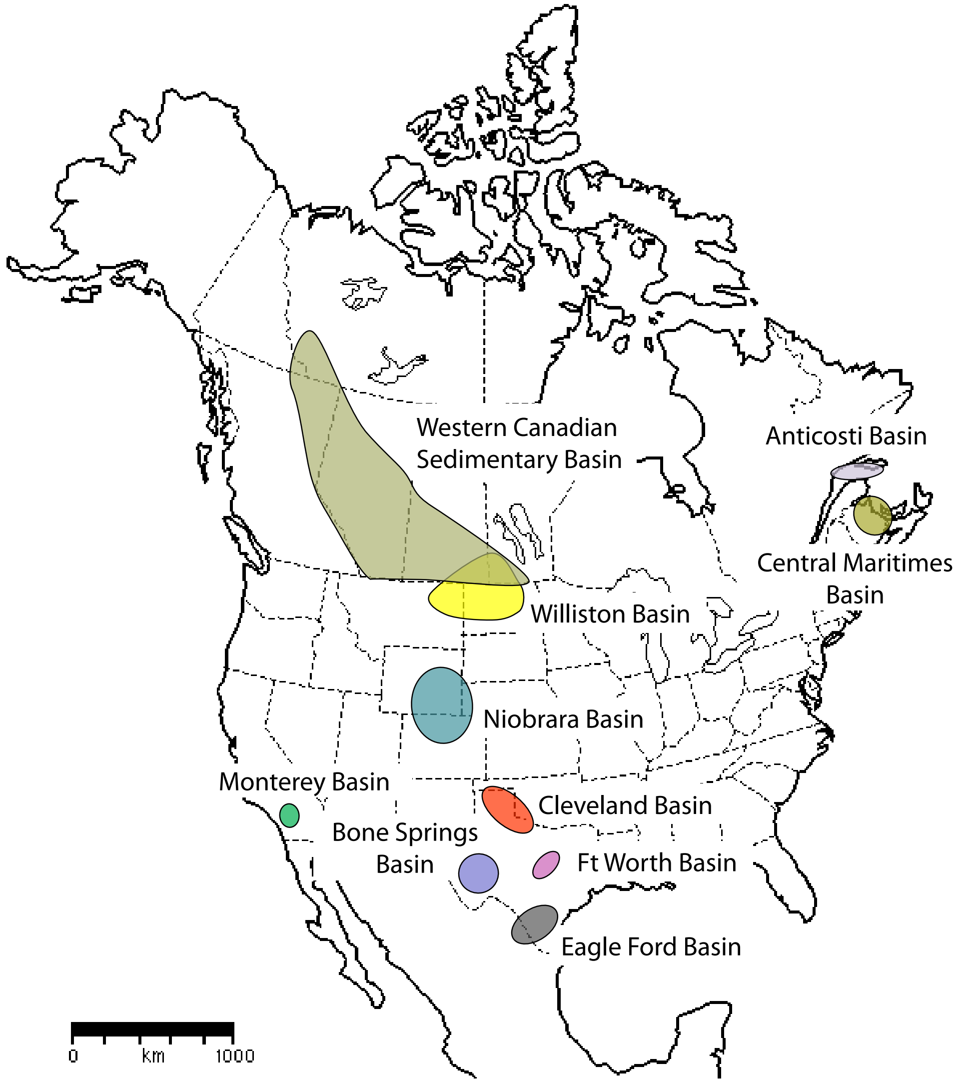
Source: Macquarie Group

Oil bearing formations in Western Canada illustrating the amount of oil recovered to date compared to the estimated original oil in place (OOIP). The percentage value reflects the amount of oil that has been recovered from the reservoir to date.

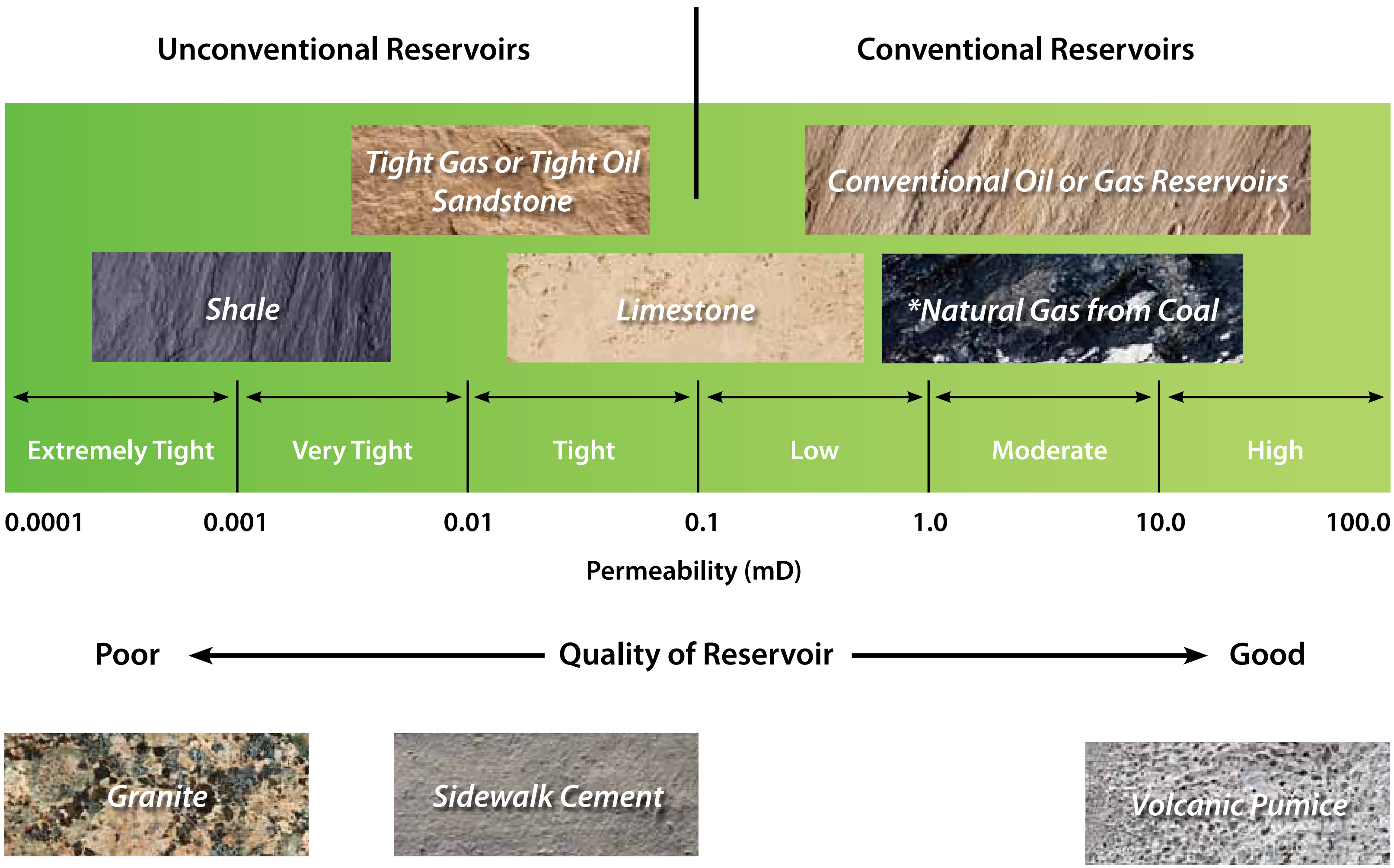
Where is Tight Oil Found?

Tight oil is found throughout Canada's known oil-producing regions as well as numerous basins in the United States.

The industry has explored for and developed conventional oil reservoirs for many years. As these resources have diminished, companies have expanded their search to look at new sources of oil, such as shale oil and other tight oil reservoirs. Drilling and completion technologies used to produce unconventional resources are also being applied to increase oil production from some conventional oil reservoirs where recovery has been low.



Major basins with potential for tight oil development are illustrated above.

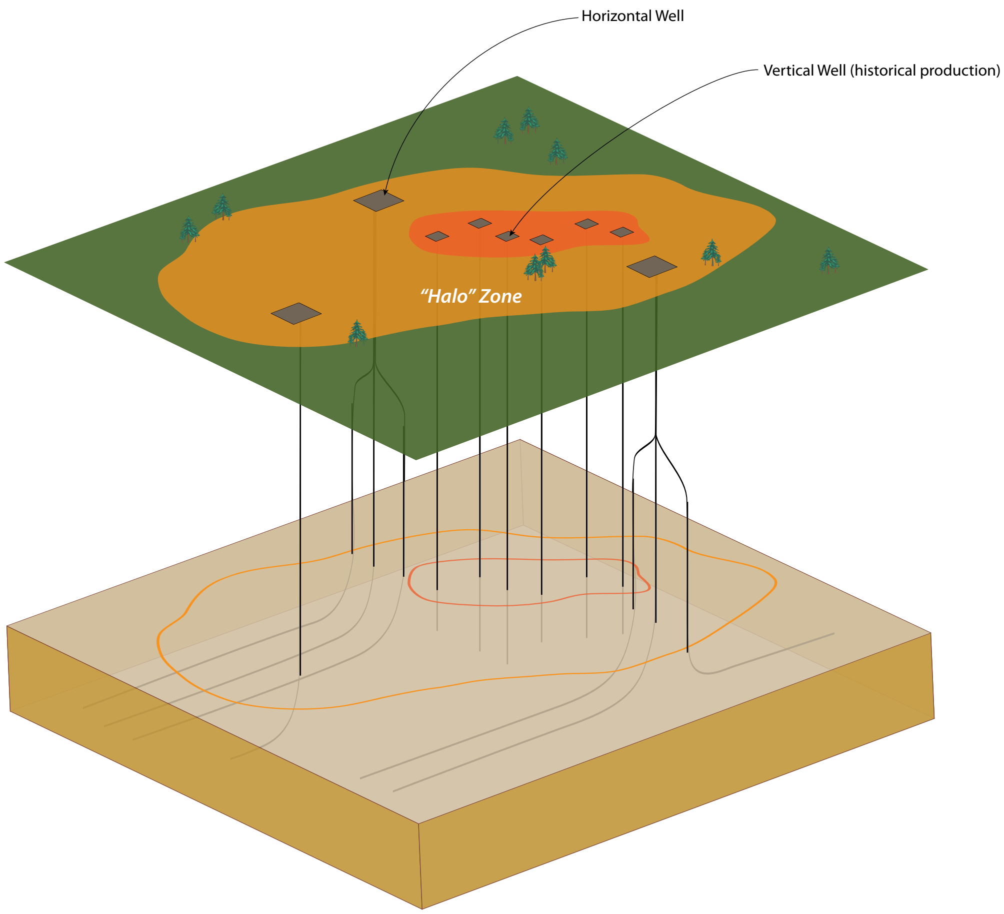


** Natural Gas from Coal reservoirs are classified as unconventional due to type of gas storage*

Modified from US Department of Energy

Types of Tight Oil Plays

In the oil and gas industry, the types of oil and gas deposits are generally classified into different categories called "Plays". Plays are differentiated based on geology and the technology required to produce the oil.
There are numerous play types associated with tight oil:



Conventional Oil Play

Unconventional Oil Play

Halo play

In some existing oil fields, the fringe regions, or halos, surrounding the areas of historical production, are known to contain oil. The reservoir properties in the halo are not as favorable as those within the previously developed area. Applying new technologies, such as horizontal drilling, allows oil to be recovered from the halo or fringe regions. Examples of this type of play are the Cardium and Viking Formations in Western Canada.

Geo-stratigraphic Play

This type of play describes a geological formation known to contain significant oil resources over a large geographic region. This type of play also requires the use of advanced technology to yield economic oil production. The Middle Bakken Formation, which occurs in parts of Saskatchewan, North Dakota and Montana, is an example of this type of play. It contains oil that has been sourced from the overlying and underlying organic rich shale units.

Upper Bakken - organic rich shale unit

Middle Bakken - fine grained dolostone

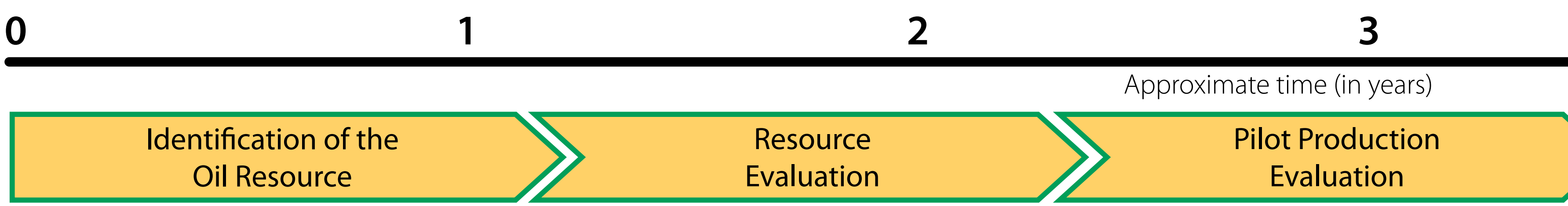
Lower Bakken - organic rich shale unit

Shale Oil Play

In shale oil plays, the rock material is predominantly organic-rich shale which contains oil. The rock is not only the source of the oil but also the reservoir. Shale reservoirs tend to have "tighter" permeability than sand or carbonate tight oil reservoirs and may require a different type of completion technique. An example of a shale oil reservoir with potential to produce would be the Exshaw Formation in southern Alberta.

What does Tight Oil Exploration and Development look like?

The Canadian Society for Unconventional Resources has developed a schematic time chart for the various stages of unconventional resource development. These stages are based upon the premise that certain types of oil and gas exploration and development are undertaken at specific stages in the life of a project. Continuation of the project to the next stage is dependent on successful results from the exploration activities as well as a positive economic and investment environment. The stages, along with a brief description of typical types of industry activity, are illustrated in the figure below.



Stage 1:
Identification of the Oil Resource

Subsurface information from existing wells as well as archived seismic data can provide the key indicators of a potential tight oil resource.

Stage 2:
Resource Evaluation

Land Acquisition and the securing of seismic data lead to drilling location permits and land use agreements. Initially, vertical wells are drilled to evaluate the reservoir properties and resource potential – commonly core samples are collected.

Stage 3:
Pilot Production Evaluation

Drilling of initial horizontal well(s) and potential completion techniques to determine production potential. Some level of multi-stage fracturing may take place at this point. Planning and acquisition of pipeline right-of-ways for field development also occurs during this stage.

Tight oil development can be categorized into two types of exploration and development; Halo (Infill) and Greenfield. In regions where existing historical conventional oil wells have been drilled, much of the new activity is classified as Infill or Halo. In these areas, tight oil development usually begins at Stage 3, Pilot Project Evaluation, where unconventional technologies are applied to a known reservoir. Companies are looking to utilize these advanced technologies to improve the overall productivity of the new oil wells.

In contrast, Greenfield exploration activities lie within regions where the resource potential of the oil bearing formations has not yet been established and requires more structured exploration planning. In these areas, Stages 1 and 2 are often undertaken before proceeding with pilot projects (Stages 3 and 4).

Stage 4:
Pilot Production Testing

Drilling of multiple horizontal wells from a single pad as part of a full size pilot project.

Optimization of completion techniques including drilling and multi-stage fracturing and micro-seismic surveys. Planning and acquisition of pipeline right-of-ways for field development.

Stage 5:
Commercial Development

Drilling and completion proceeds based upon the field development plan as defined by regulatory well spacing, government approvals for construction of facilities and applicable technologies identified during the evaluation stage(s). Optimization of completion techniques, including multiple horizontal wells, multi-stage fracturing and micro-seismic monitoring also occur at this stage.

Stage 6:
Project Completion and Reclamation

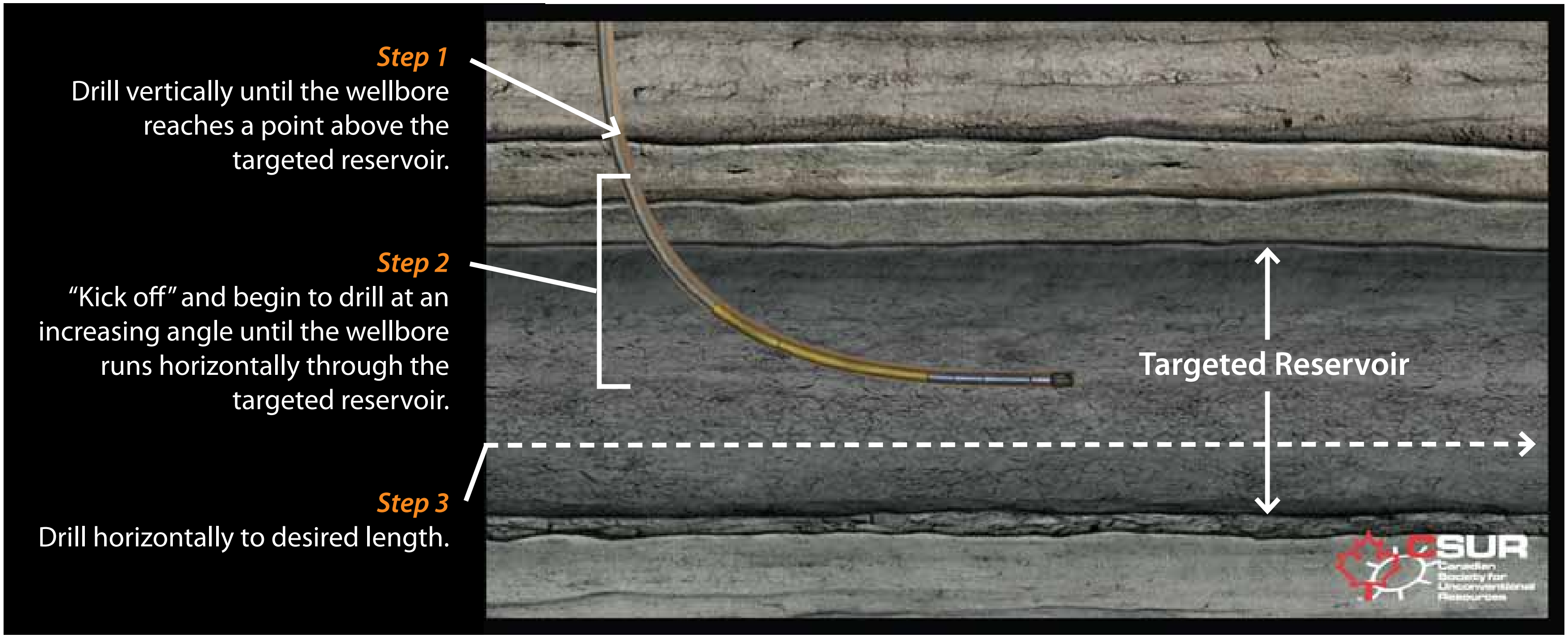
Completion of a project and reclamation of development sites and well pads to regulator standards occur as part of this final stage.

Technologies Used to Recover Tight Oil

The oil which is produced or extracted from tight reservoirs is the same type of oil which can be produced from conventional reservoirs. It is the application of advanced technologies which make these developments unconventional. Different technologies are used for different plays but the most common methods used today are horizontal drilling and multi-stage hydraulic fracturing.

Horizontal drilling

The purpose of drilling a horizontal well is to increase the contact between the reservoir and the wellbore. Wells are drilled vertically to a predetermined depth (typically 1000m to 3000m below the surface depending on location) above the tight oil reservoir. The well is then "kicked off" (turned) at an increasing angle until it runs parallel within the reservoir. Once horizontal, the well is drilled to a selected length which can extend up to 3-4 km (2-2.5 miles). This portion of the well is called the horizontal leg.



Hydraulic Fracturing

Tight oil reservoirs require some form of stimulation once the well has been drilled. The most common type of stimulation used by the oil and gas industry is referred to as hydraulic fracturing or fracking. This process applies pressure by pumping fluids into the wellbore which opens existing, or creates new fractures or pathways in the reservoir through which the oil can flow to the wellbore. In conventional oil reservoirs the reservoir permeability is sufficient that hydraulic fracturing may not be needed to achieve economic production rates. In unconventional oil, the reservoir permeability is typically very low and additional pathways must be created to enable the flow of hydrocarbons.

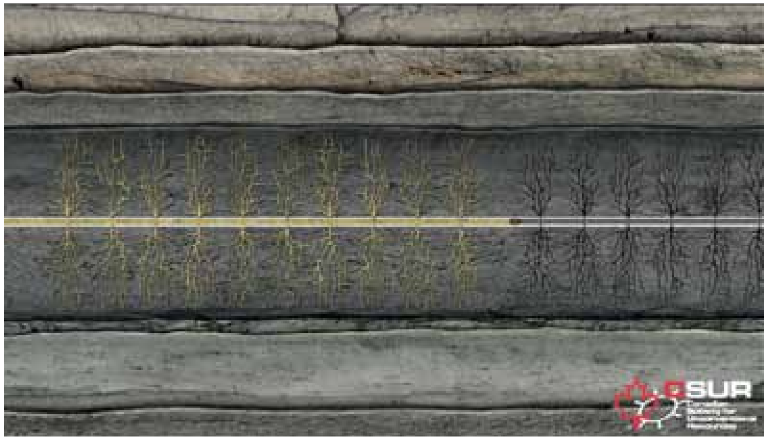
To create the fractures, fluids are pumped under pressure from surface into the reservoir, many hundreds to thousands of meters below ground. The type of fracture fluids used will vary depending on the reservoir characteristics. Commonly, water is used as a base fluid. Generally, three to twelve additives are added to the water, based on the characteristics of the source water and also of the formation to be fractured. These additives represent 0.5% to 2% of the total fracturing fluid volume. Their purpose is to reduce friction, prevent microorganism growth/biofouling and prevent corrosion.

As part of the stimulation process, once the fractures have been created, sand or ceramic beads (proppants) are pumped into these small openings to hold open the fractures created. The volume of fracture fluid and proppant used for each hydraulic fracture varies dependent upon the anticipated production rates following the treatment.

In tight oil wells, the hydraulic fracturing process typically involves multiple stages along the well bore. Each stage is isolated using packers or plugs to contain the fracturing fluids and ensure that the fracture grows in the direction and distance that was planned.

For more information on hydraulic fracturing see *Understanding Hydraulic Fracturing* at www.csur.com.

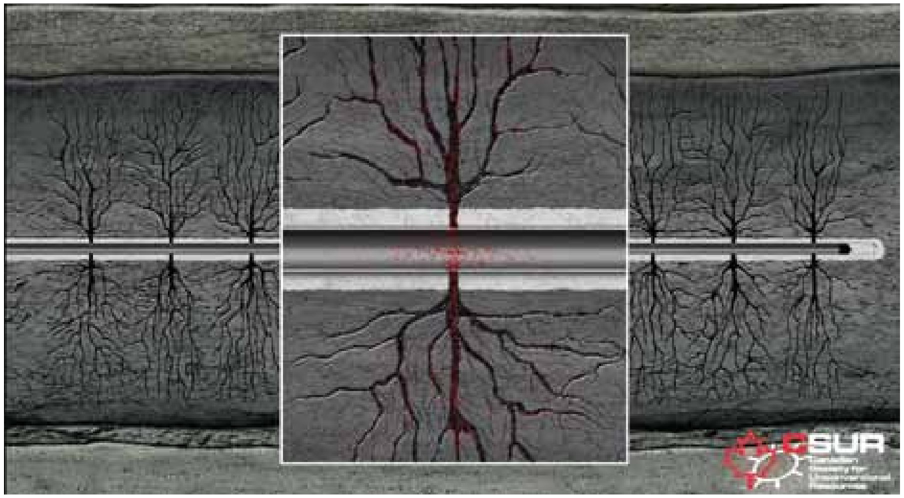
The image to the right shows two fracture stimulations; the darkened fractures were completed as one stage and are temporarily isolated while those shown in yellow occur as the next stage. The number of fractures required in a wellbore will vary based on the characteristics of the target formation.



Micro-seismic

Magnitude

A seismic event may occur from natural or man-made (induced) causes that create sound waves in the earth. A seismic event may be caused by an event ranging from a devastating earthquake to something as common as dropping an object from your hand. Micro-seismic events, as the name suggests, are approximately 1 million times smaller than any tremor that may be felt by a human. Micro-seismic events associated with hydraulic fracturing are man-made events generated during the process which creates pathways for hydrocarbons to flow to the wellbore. These micro-seismic events are very small; they release energy roughly equivalent to a gallon of milk falling from a kitchen counter and their detection, as explained below, requires sensitive and sophisticated equipment. The fractures, or cracks, are generally only wide enough to allow a grain of sand or small ceramic bead to become lodged within these cracks; providing the path for hydrocarbon flow.



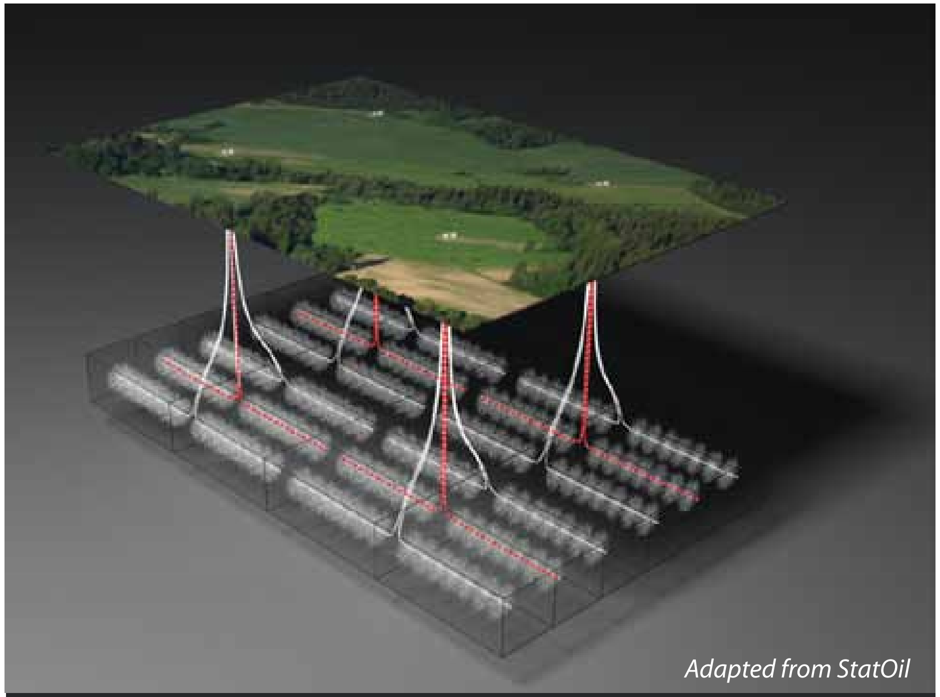
Monitoring

During fracture stimulation operations, it is important to know where the fractures are being created in the reservoir. Monitoring of the fracturing process in real time can be accomplished using a variety of techniques. Pressure responses and micro-seismic monitoring are two such techniques.

Measuring micro-seismic events that are occurring as the fracture stimulation takes place provides industry professionals with visual evidence that fractures are being developed both vertically and horizontally. Because these micro-seismic events are measured in real time, immediate adjustments can be made during the operation to ensure that the fractures created stay within the zone that has production potential. The magnitude of seismic events created using hydraulic fracturing techniques is many times smaller than events which can be felt at surface.

Following completion of fracturing operations, the micro-seismic model can be used to define the limit and reach of each fracture stimulation in the wellbore(s). The horizontal and vertical model is also used to define recoverable resources, areas of insufficient stimulation and a visual assurance that potential groundwater sources are protected.

Schematic diagram illustrating fractures created during the multi-stage hydraulic stimulation process



Initial horizontal wells are shown above in white.

Red dashed lines indicate infill drilling activity.

Initial Production

Once pathways have been created within the tight oil reservoir, allowing the oil to flow to the wellbore, conventional methods are used to produce the well. These can include pump jacks which lift the oil to the surface, storage tank facilities (commonly referred to as batteries) and pipelines and trucks used for transport. Well production is commonly robust in the early stages of production but will decline over time.

Infill Drilling

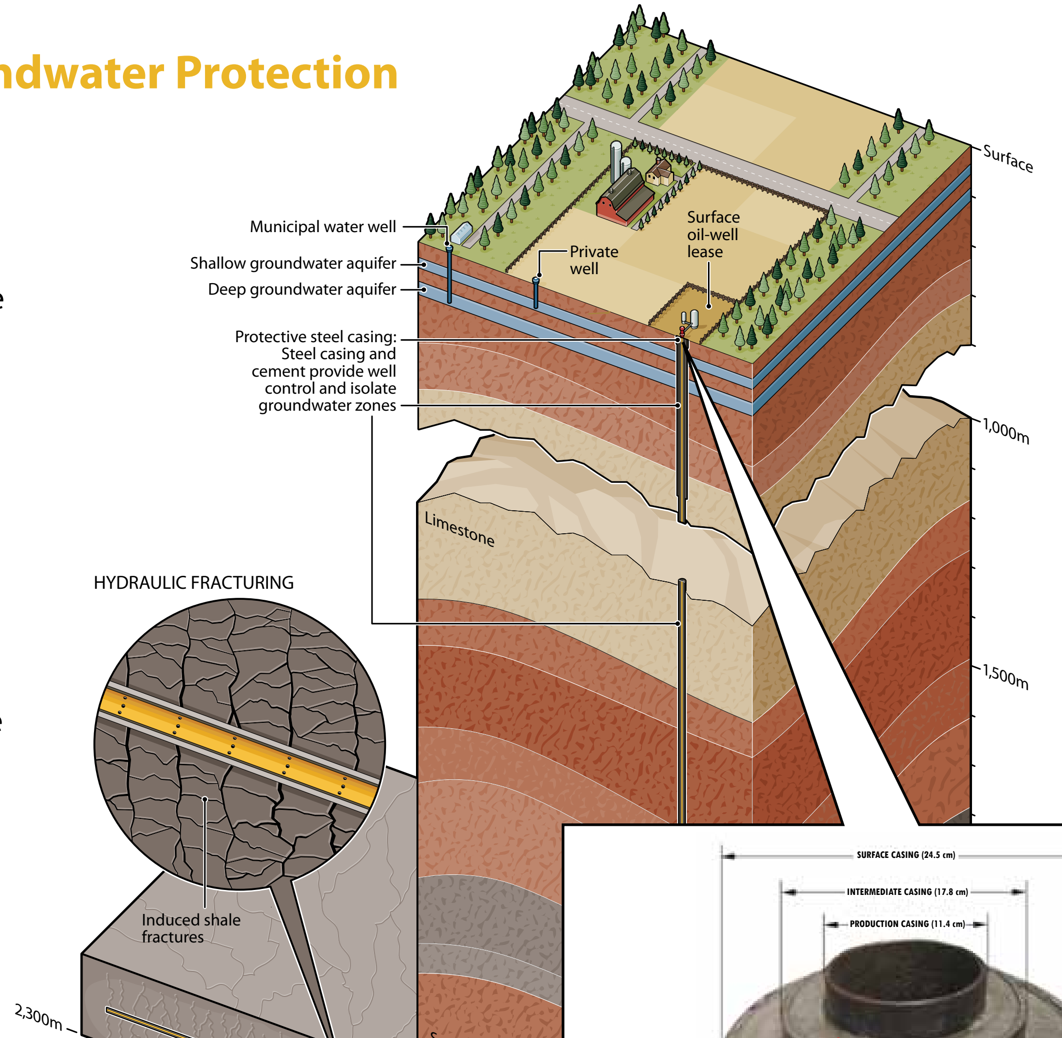
In many cases, tight oil development is used to increase the overall recovery of oil from an existing field. Infill wells are located amongst existing conventional wells. The purpose of these wells is to extract additional oil which has not been recovered using conventional production technology. In contrast, Halo wells are located on the fringes of the existing field and rely upon the utilization of new technology to expand the boundaries of the productive zone or "sweet spot" within the oil bearing formation.

Wellbore Construction and Groundwater Protection

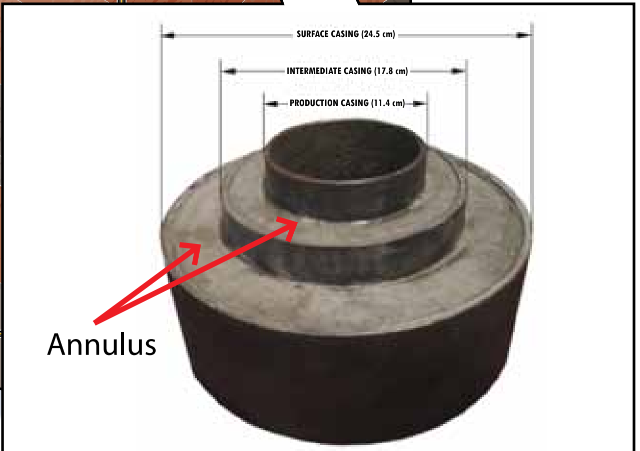
Proper well construction isolates the wellbore; a critical step taken by the oil and gas industry to protect potential groundwater sources which may be encountered during the drilling process. There are typically three different sets of steel casing which are individually cemented into the wellbore to provide barriers which isolate wellbore fluids from the rock intervals.

After each string of casing is installed in the well, cement is pumped down the center of the casing (surface, intermediate or production) and circulates back to the surface in the space outside of the casing. This space is commonly referred to as the annulus. After each of these steps are completed, the cement is allowed to set prior to the continuation of drilling and, in some places, a "cement bond" geophysical log is run to determine the integrity of the cement that surrounds the casing. This extra measure is taken to ensure that the wellbore is adequately cemented and capable of withstanding the pressures associated with hydraulic fracturing. Prior to stimulation, the well is pressure tested to ensure the integrity of the casing system that has been installed in the ground.

To learn more about water protection and use see *Understanding Water and Unconventional Resources* at www.csur.com.



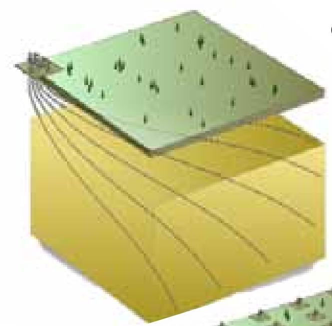
Adapted from Canadian Natural Gas

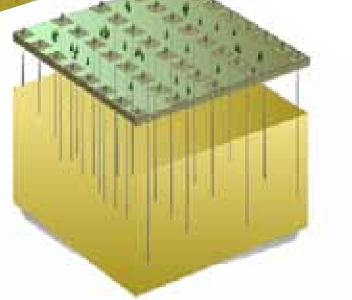


Adapted from Questerre Energy Corp.

Minimizing Footprint

Economical production of oil from low permeability reservoirs has been made commercially viable through the application of technologies such as horizontal drilling and multi-stage hydraulic fracturing. Companies are striving to reduce environmental impacts and to minimize costs associated with tight oil development. The application of multiple wells from a single pad has been recognized as an opportunity to achieve both of these objectives. While the size of a multi-well pad is slightly bigger than a regular oil and gas lease, the cumulative footprint for a tight oil field development is much smaller than it would be using vertical wells. Fewer access roads are required and the concentration of facilities and pipelines within the pad minimizes surface disturbance.





Source: Encana Corp.

Horizontal multi-well pad during completions activity

Source: Encana Corp.

During the drilling and completion of the well, there is a significant space requirement for the equipment used. Once the well has been completed and commercial production initiated, the lease site requirements are typically reduced by as much as 50%. The space, which had been required for drilling and completions activities, is reclaimed to the condition that it was found prior to industry activity.

Horizontal multi-well pad in production

Source: Trident Exploration

Glossary and Terminology

Annulus: The space between two concentric objects, such as between the wellbore and casing or between casing and tubing, where fluid can flow.

Aquifer: The sub-surface layer of rock or unconsolidated material that allows water to flow within it. Aquifers can act as sources of groundwater, both usable fresh water and unusable saline water.

Casing: Steel pipe placed in a well and cemented in place to isolate water, gas and oil from other formations and maintain hole stability.

Carbonates: Sedimentary rocks that are rich in calcium or magnesium carbonate such as limestone or dolomite. The dissolution spaces (vugs) associated with these types of rock can contain oil or gas.

Completion: The activities and methods of preparing a well for the production of oil and gas.

Flowback: The flow of fracture fluid back to the wellbore after the hydraulic fracturing treatment is completed.

Formation: A formation consists of a number of rock units that have a comparable lithology, facies or other similar properties. Formations are not defined on the thickness of the rock units they consist of and the thickness of different formations can therefore vary widely.

Horizontal Drilling: A drilling procedure in which the wellbore is drilled vertically to a kick-off depth above the target formation and then angled through a wide 90 degree arc such that the producing portion of the well extends horizontally through the target formation.

Hydraulic Fracturing (aka 'Fracking'): A method of improving the permeability of a reservoir by pumping fluids such as water, carbon dioxide, nitrogen or propane into the reservoir at sufficient pressure to crack or fracture the rock. The opening of natural fractures or the creation of artificial fractures to create pathways by which the oil can flow to the wellbore.

Multi-stage Fracturing: The process of undertaking multiple fracture stimulations in the reservoir section where parts of the reservoir are isolated and fractured separately.

Permeability: The ability of the rock to pass fluids or oil through it. The higher the permeability number, the greater the amount of fluid or oil that can flow through the rock. Permeability is measured in a unit called Darcies. Conventional reservoirs may have permeabilities in the 10's to 100's of milliDarcies or occasionally Darcy range. Unconventional or tight reservoirs usually have permeabilities in the micro to nanoDarcy (one millionth of a milliDarcy) range.

Play: The extent of a petroleum-bearing unit within a formation.

Porosity: The free space within the fine grained rock that can store hydrocarbons.

Propping Agents/Proppants: Non-compressible material, usually sand or ceramic beads, that is added to the fracture fluid and pumped into the open fractures to prop them open once the fracturing pressures are removed.

Reservoir: The rock that contains potentially economic amounts of hydrocarbons.

Reclamation: The act of restoring something to a state suitable for use.

Stimulation: Any process undertaken to improve the productivity of the hydrocarbon bearing zone (e.g., formation fracturing).

Sweet spot: The specific area within the reservoir where a large amount of gas is accessible.

Tight Oil: Oil found within reservoirs with very low permeability which typically will not flow to the wellbore at economic rates without assistance from technologically advanced stimulation treatments or recovery processes.

Vug: A small cavern or cavity within a carbonate rock.

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