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Citation

Coutret, H. C. (2000). Engineering Aspects of the Implied Covenant to Protect Against Drainage. *Annual of the Arkansas Natural Resources Law Institute*. Retrieved from <https://scholarworks.uark.edu/anrlaw/116>

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THE ENGINEERING ASPECTS
OF THE IMPLIED COVENANT
TO PROTECT AGAINST
DRAINAGE

Henry C. Coutret

**ENGINEERING ASPECTS OF THE IMPLIED COVENANT
TO PROTECT AGAINST DRAINAGE**

**39th Annual Natural Resources Law Institute
Hot Springs, Arkansas
February 23-26, 2000**

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ENGINEERING ASPECTS OF THE IMPLIED COVENANT
TO PROTECT AGAINST DRAINAGE

(Henry C. Coutret, Jr., November 1, 1999)

The term drainage has three primary, but somewhat different, applications in the oil, gas, and brine industries. These are as follows:

1. Drainage as it applies to determining well spacing.
2. Drainage as it applies to expressed or implied lease covenant to protect the lease premises (protection covenant).
3. Drainage resulting from the forced migration of injected fluids.

In the well spacing application drainage testimony provides the basis for the Arkansas Oil and Gas Commission or any other regulatory agency to determine the size of drilling and production units. The Arkansas statute, which is similar to the statute in most states, provides that a drilling unit means “the maximum area which may be efficiently and economically drained by one well . . .” In this application the meaning of the term “drainage” is quite clear. It is the area originally underlain by the hydrocarbons that would ultimately be produced during the life of a typical well. In the second application of the term “drainage” to the protection covenant, either for the purpose of proving that substantial drainage has occurred or in determining damages, the meaning is not so clear. Court testimony by expert witnesses is frequently confusing, because it can be based on three very different concepts of what the term “drainage” means. This paper deals with these different concepts and their implications as to the calculated quantity of hydrocarbons drained. The third application of drainage, forced migration, is not so common in oil and gas matters because unitization is required for reservoirs with fluid injection projects, but it has been the issue in several lawsuits involving brine production in the bromine industry. In this application the meaning of drainage is fairly clear. It would be the volume of native fluid displaced from under a tract and replaced by forced migration of injected fluid.

Having had the opportunity to participate as an expert witness in a number of lawsuits involving issues of drainage, it has become clear to me that there are a number of issues related to

drainage controversies that must be clearly defined so the witness and lawyer can work effectively together. In this paper I discuss the most difficult question of all and that is, just exactly what constitutes drainage. I conclude by discussing some other drainage issues that sometimes are not clearly understood by expert witnesses and attorneys.

In lawsuits involving oil and gas matters, drainage is an issue most commonly related to the implied protection covenant of a lease. A lessee has a duty to act in the manner of a prudent operator to protect against the drainage of oil and gas to an adjacent lease. The implied covenant to protect from drainage can be viewed as a logical derivative of the Rule of Capture by putting the lessor in the same position he would have been in with respect to drainage if he had not leased his land for hydrocarbon development. Surely if the owner of a well is entitled under the Rule of Capture to drain hydrocarbons from adjoining land, it is only logical that when leasing the adjoining land there is an implied obligation on the part of the lessee to protect the lessor from drainage, since in granting the lessee the exclusive right to develop his lease the lessor has given up the only means by which he can protect his lease from drainage - to drill a protection well. Basically, this covenant requires the lessee to drill an offset well to protect a lessor from drainage when a prudent operator would do so. In the early years of the industry, lease cancellation was frequently the remedy sought and received. More recently the more common remedy includes damages based on the volume of hydrocarbons drained away although lease cancellation is still available in certain cases.

There are three main reasons for participation of a reservoir engineer in a protective covenant lawsuit. The first reason is to provide expert witness testimony that substantial drainage from the leasehold has taken place as a result of production from an offset well. (This is one of the elements for a cause of action for a breach of the implied duty to protect.) The second reason is that in most drainage lawsuits damages are the remedy for past drainage, and the volume of hydrocarbons drained away provides a reasonable basis for determination of the amount of damages. The third reason is to offer evidence that the lessee of the drained lease did or did not act as a prudent operator in failing to drill a protection well. (This is the other element for a cause of action.)

When the covenant to protect against drainage was first recognized as an implied obligation of a lessee, the most common remedies were requiring the drilling of a protection well on the drained lease, lease cancellation, or some combination of these two. Neither of these remedies required a

specific understanding of what constitutes drainage. It is quite satisfactory to only understand that drainage is what happens to a lease when it has not been drilled but is adjacent to a lease with a well which has been completed in a common reservoir underlying both leases. Even when the courts began to more commonly recognized monetary damages as the proper remedy for failure to protect from drainage, there were two ways to approach quantifying damages. Damages could be based on what a protection well would have produced if it had been drilled or they could be based on the volume of hydrocarbons drained away. If the “volume of hydrocarbons that would have been produced” approach is taken, a specific understanding of what constitutes drainage is still not required. If an expert witness can reliably determine what the undrilled protection well would have produced if it had been drilled, it really does not matter what his concept of drainage is. Frequently, what a well would have produced can be estimated based on a simple analogy with the offsetting well. It is when you use the “volume drained away” approach that a specific understanding of the meaning of “drainage” is required. There is some logic behind both approaches. In my own experience though, if drainage has occurred the client and attorney expect me to base the damage analysis on the volume of hydrocarbons drained away. In this paper I am not addressing the method of determining damages by the “volume of hydrocarbons that would have been produced” approach. My paper deals with the problems of understanding what constitutes drainage when an engineering witness is asked to determine the volume of hydrocarbons drained away.

The fact is that drainage, as we use the term relative to the protection covenant, is a pretty abstract concept. To illustrate why I say this let me contrast the idea of drainage with the concept of displacement of a hydrocarbon by an injected fluid. In a displacement process, for example a waterflood, injected water moves through pore space displacing some of the hydrocarbons and leaving a water saturation where hydrocarbons had been previously. If injected water invades an offsetting lease it is clear how it has been damaged. It has been damaged to the extent that reservoir hydrocarbons have been replaced by injected water. If you can determine the reservoir volume into which water has invaded, you can quantify the lost hydrocarbons and the damages. Drainage not related to displacement is different. It involves only one fluid, the hydrocarbon, and that fluid is fugacious or transient in nature. It moves by pressure differential forces that exist in nature and that are created by production from all wells in the reservoir. When oil or gas is produced, hydrocarbons

move over wide areas and, as they move toward low pressure areas, the pore volume is not evacuated. The migrating hydrocarbons are replaced in the pores by like hydrocarbons. Unlike water displacing oil we have hydrocarbons replacing like hydrocarbons, so how do we identify the volume that has been drained?

What Constitutes Drainage

If we are to quantify drainage volumes we must answer the question of exactly what constitutes drainage. There are three plausible answers: a) drainage occurs when hydrocarbons initially in place under a leasehold have been produced by an offsetting well, b) drainage occurs when the volume of recoverable hydrocarbons initially under a leasehold is reduced as a result of production from an offsetting well, and c) drainage occurs when hydrocarbons initially in place under a leasehold have migrated to an adjoining lease as a result of production from an offsetting well. Any of these answers might be correct but the problem is they are very different. The engineer attempting to quantify the volume of hydrocarbon drained from a lease must understand which concept of drainage is being claimed in a lawsuit. None of these concepts may constitute drainage under the protection clause if the lease being drained has had a well drilled on it by the lessor or if the protection location is so poor it does not meet the prudent operator standard.

Let us now consider validity and implications of each of these three concepts of what constitutes drainage.

a) Drainage occurs when the volume of recoverable hydrocarbons initially in place under a leasehold have been produced by an offsetting well. This is the most widely held idea of what constitutes drainage. The reason is that this is the concept that we apply when we calculate drainage area of a well. When a well is first put into production, the molecules first produced are those nearest the wellbore. As the well continues to produce, the hydrocarbon molecules that are produced are moving to the well from further out in the reservoir. As you can imagine, the drainage area of a well begins by being a small circular area around the well that grows progressively larger as the well is produced. In time the drainage area gets less radial as reservoir flow patterns are influenced by reservoir heterogeneities, flow barriers, and pressure differentials. In the context of a Field Rules Hearing when the issue is the drainage area of the well, we are talking about the size of the area under which hydrocarbons were originally located that during the well's life will move to the

wellbore and be produced. As an example, if we could determine that an oil well would ultimately recover 250,000 barrels and could volumetrically calculate from the reservoir properties that on average the well would produce 250 barrels per acre-foot, we would know that the drainage volume is 1,000 acre-feet and if the reservoir were uniformly 20 feet thick we would know that the drainage area was 50 acres. This drainage area would encompass a somewhat distorted circle around the well of 50 acres in size. Within this distorted circle, every acre-foot would not have had 250 barrels drained from it. Drainage would have been greatest near the wellbore and least at the boundary of the circle. In this example the region of the reservoir next to the well may have had 750 barrels per acre-foot drained from it where at the extreme edge of the drainage area less than 1 barrel per acre-foot would have been drained. The 250 barrels per acre-foot used in the calculation was the average over the entire drainage area. Applying this concept in the context of the protection covenant, if as a result of production from a well, the distorted circular drainage area extends onto an offsetting lease, that lease would have suffered drainage because being inside the drainage area meant that some of the hydrocarbon molecules that were originally under the offsetting lease had been produced by the well. The area drained could be defined and the volume of hydrocarbons drained away could be determined. This, in many applications, is a reasonable concept of drainage which, within limits of engineering accuracy, can be readily quantified. The volume of drained hydrocarbons determined by this approach would have been produced by the offsetting well and removed from the reservoir. This approach is illustrated in Figure 1.

b) Drainage occurs when the volume of recoverable hydrocarbons initially under a leasehold is reduced as a result of production from an offsetting well. This is a very different way of looking at drainage. If the volume of in-place and recoverable hydrocarbons has been reduced under a leasehold by virtue of production from an offsetting well, would it not be correct to say that it had suffered drainage and should be entitled to the relief afforded by the protection covenant. The production of a well will reduce pressure over much wider areas than the drainage area described above. Particularly in a gas reservoir, as pressure is lost, reserves are lost. It makes some sense to say that the amount of damage a leasehold has suffered by drainage from an offsetting well is based on the volume of hydrocarbons originally in place less the volume of hydrocarbons in place after suffering offset drainage. This approach is illustrated in Figure 2. This is a two-way street though.

Consider the situation of a leasehold that is well updip of a strong aquifer but is offset by a high capacity well in an even higher upstructure location. This updip offset may have drained away most of the hydrocarbons originally under the leasehold, but if the strong water drive resulted in downdip oil migrating onto the leasehold as fast as it is drained away by the updip well, there would be no net drainage. What I have described is in fact the concept of “net drainage” that is recognized by some jurisdictions, Texas in particular. This too is a reasonable concept of drainage that within engineering accuracy can be readily quantified. The only problem is that this concept of drainage is totally different from that described in a) above.

c) Drainage occurs when hydrocarbons initially in place under a leasehold have migrated to an adjoining lease as a result of production from an offsetting well. This third concept of drainage is not as easy to accurately quantify as the two concepts previously described but it is easy to understand and explain to a judge or jury. It also is the method that will indicate the greatest volume of hydrocarbons drained away from a leasehold so it has much appeal to plaintiff’s attorneys in a protection covenant lawsuit. This concept of drainage has nothing to do with the drainage area of the offsetting well. If an offsetting well causes hydrocarbons to migrate off a leasehold to an adjacent lease, drainage has occurred. The focus in this concept is not where the hydrocarbons produced by an offsetting well came from, but where the offsetting well caused the hydrocarbons originally in place to go. This approach is illustrated in Figure 3. The problem with this concept is that hydrocarbons being fugacious in nature will migrate under any pressure differential. Hydrocarbons that migrate off a lease can, under different pressure differentials, migrate back on to the lease. It also raises the question of conflict with the rule of capture if the hydrocarbons that have migrated off the leasehold have never been produced and reduced to possession but are still available in the reservoir to be produced. This is a widely accepted concept of drainage and the problem is that this concept is totally different from that described in a) and that described in b) above.

Engineering Aspects of Reservoir Fluid Flow and Drainage

The difficulty of simply defining drainage arises from the fact that when a well is completed and put into production in a reservoir, it sets up a chain reaction of the produced hydrocarbon molecules being replaced by adjacent molecules, which are replaced by adjacent molecules, and this chain moves out into the reservoir until a reservoir boundary is encountered.

Consider the simple example of a very permeable oil reservoir developed on a forty acre spacing pattern in which the discovery well, drilled at the center of the forty acre unit, has produced 5000 barrels of oil in its first month of production. This example is shown in Figure 4. The most distant molecule that was actually produced from the well was only 65 feet away from the wellbore. As a result of that well 1000 barrels of oil originally under the north offset unit has moved under the unit of the discovery well. The north offset unit, however, benefitted from 975 barrels of oil which moved on to the unit from adjacent units to replace the oil that migrated to the south. The north offset unit had 1000 barrels of oil originally under it migrate off the lease because of the discovery well. It now has 25 barrels of oil less under it than it had originally. The discovery well never produced a drop of oil that was not originally under its unit and, in fact, very close to its wellbore. The question that would be posed to the engineering witness would be: Was the north offsetting tract drained and if so, what was the drainage volume? The totally honest witness using method a) would say "No." The totally honest witness using method b) would say "Yes, but only 25 barrels had been drained." The totally honest witness using method c) would say "Yes, and 1000 barrels had been drained off the lease." The problem is not with their calculation of drainage volumes, but that all three are calculating something different and calling it drainage. As simplistic as this example is, it shows exactly why it is important for the engineering witness and the attorney to share a common understanding as to what constitutes drainage.

It is unfortunate that the courts have not given us a better understanding as to what constitutes drainage. A fundamental question that needs to be answered is: Has drainage occurred until hydrocarbons originally under a lease have been produced from an offsetting well? Recognizing the fugacious nature of hydrocarbons, can it be considered drainage when hydrocarbons move off the lease premises but are still in the reservoir where they could potentially be recaptured? There is an argument to be made that it may be best that the courts have not given us one single definition of drainage. It may be that the appropriate definition depends on the circumstances of the case at hand. Definition a) would be applicable in all reservoir types. It is the most conservative yet most solid definition. It is the proper definition if drained hydrocarbons must be actually produced by an offsetting well for drainage to have occurred. Definition b) provides a very fair and equitable measure of damages in depletion drive or solution gas drive reservoirs but is inappropriate and, in

most cases, inequitable as a measure of drainage damages in a water drive reservoir. Definition c) makes the most sense when applied to water drive reservoirs. This is because, in most cases when hydrocarbons are displaced off a tract by an advancing water front they will never be recovered by a well on that tract, so the fact that the displaced hydrocarbons are still in the reservoir becomes meaningless if they cannot be captured by a well on the offended tract.

Another important issue is the question of just how accurately can these drainage volumes be calculated. In most cases where the geology and reservoir geometry are not too complicated, drainage volumes can be calculated with reasonable accuracy using conventional volumetric and material balance method. Some interpretation is usually required, and generalizations are necessary about reservoir rock, fluid, and flow properties, but in most cases a qualified witness, well informed on the issues and facts and having used accepted methodology in making the analysis, should be able to render an informed opinion that would not be considered speculation or conjecture. Computer reservoir simulation, although expensive to use, permits a more accurate determination of drainage volumes and provides a method for making reasonable estimates of drainage volumes in reservoirs with more complicated geology or well geometry or in cases where reservoir rock properties are not homogenous.

Other Significant Questions Related to Drainage

Aside from the question of what constitutes drainage there are a number of other significant aspects of drainage lawsuits on which courts and other legal authorities have given us some guidance. The aspects that I will discuss briefly are, for the most part, legal considerations but the ones I will discuss are matters which must be taken into account by an engineer preparing expert witness testimony in a drainage lawsuit.

Is drainage determined on a zone- by- zone basis or by treating all zones together?

The protection covenant applies separately to each separate reservoir. A lessee is not relieved of its obligation to protect a property from drainage where the drainage of hydrocarbons from one producing zone is offset by wells on the leasehold which drain the neighboring property in another zone.¹

What is the effect of the drained lease and the draining lease having a common lessor?

In general, a lessee will not be held in violation of the protection covenant in which

hydrocarbons have migrated to lands in which the lessor has the same or greater interest. If the lessor has a smaller interest in the lands to which the hydrocarbons moved, relief may be granted with a proportionate reduction in damages. ¹

What is the effect of the drained lease and the draining lease having a common lessee?

If a lessee, by virtue of his or his assignee's operations on an offset lease, is the cause of the drainage being suffered, many courts have held that the liability of the lessee is increased or that the burden of proof is shifted to the lessee. This type of drainage is frequently referred to as "fraudulent drainage" although it may have occurred innocently and without bad faith. The lessee might be particularly vulnerable if he is benefitting from his failure to drill a protection well beyond that which a party not owning the offset draining lease would benefit. This might be the case when the draining lease was subject to a smaller royalty than the drained lease or if the draining lease was updip to the drained lease where there was a very effective water drive. This may or may not be the case in Arkansas. Professor Phillip Norvell, in his paper discussing Sunbelt Exploration Co. v. Stephens Production Co. 896 S.W.2nd 867 (Ark. 1995) points out that in that case the Arkansas Supreme Court dismissed a fraudulent drainage argument based on Stephens role as common lessee with the adjacent unit. ^{1, 2, 3, 4}

What is the effect of unitization?

Unitization, whether it be fieldwide or localized, voluntary or forced, is a remedy for drainage. Moreover, the option of unitization should always be considered where a profitable well could not be drilled under the prudent operator standard if the option is available under the laws and regulations of the jurisdiction because it can frequently be a more cost effective means of protecting against drainage than drilling a well. ³

What do you take into account in determining if an operator has acted prudently in failing to drill an offset well?

Like with the implied covenant to develop, the prudent operator standard is applied to determine if a protection well should have been drilled to prevent drainage. Under the prudent operator standard, an operator is expected to act in the manner a hypothetical operator would to do whatever, in the circumstances would be reasonably expected and required of an operator acting in ordinary prudence, having regard for both the interests of the lessor and lessee. The application of

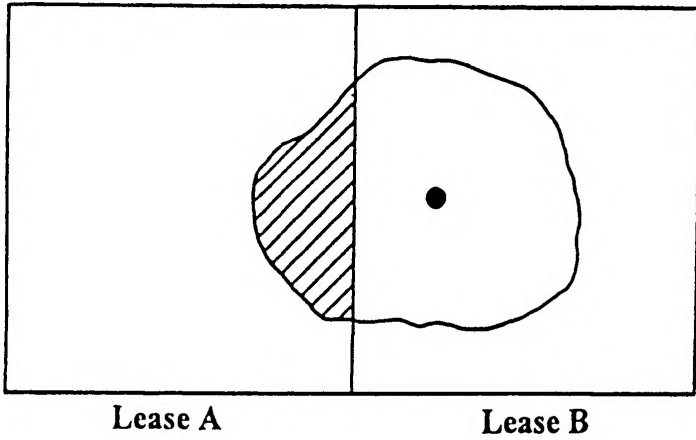
the prudent operator standard is usually somewhat differently in drainage cases than development cases because in a drainage case the lessor is actively being damaged by any delay in drilling a protection well. The hypothetical prudent operator in a drainage case would be one who stood in the position of the lessor assuming the lessor had adequate financial resources to drill the protection well. For this reason, if we were making the economic analysis to determine if the lessee acted as a prudent operator in failing to drill a protection well, we would not deduct royalty costs in determining if the lessee's economic decisions were prudent. In contrast, in a case involving the development covenant we would. We would determine net operating profit by deducting all costs of operating the well and marketing the product and then make a determination as to whether the net operating profit cash flow stream would be sufficient to induce a reasonably prudent operator to make the required capital investment, taking into account geological and drilling risks and uncertainties.^{1, 3}

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FIGURE 1

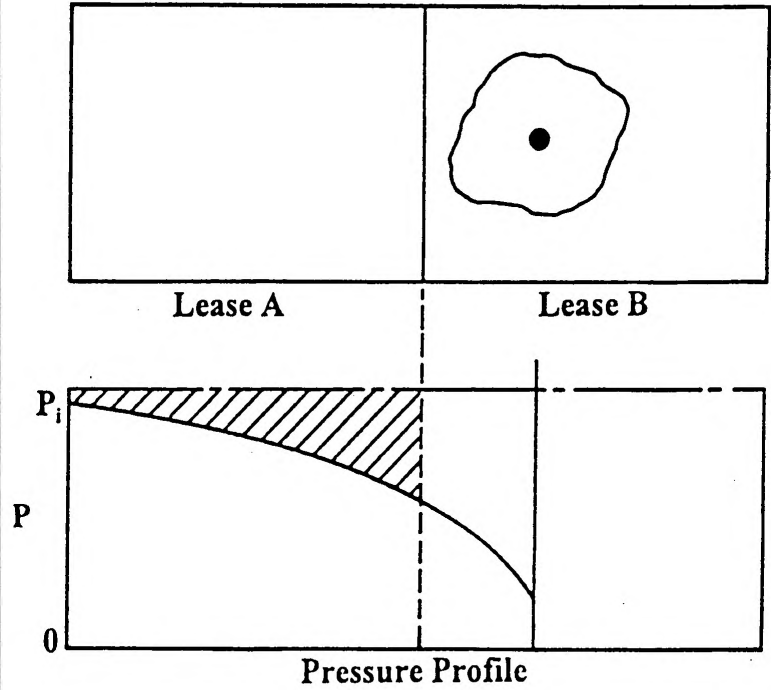
Definition a)



- Well
- Drainage Area
- ▨ Area drained by well on Lease B

FIGURE 2

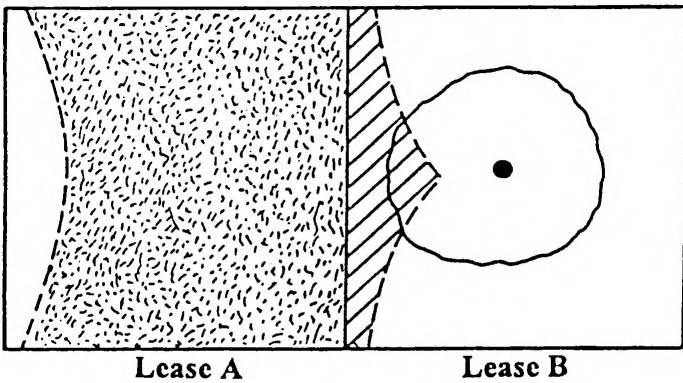
Definition b)



- Well
- Drained Area (Definition a)
- ▨ Pressure reduction due to drainage

FIGURE 3

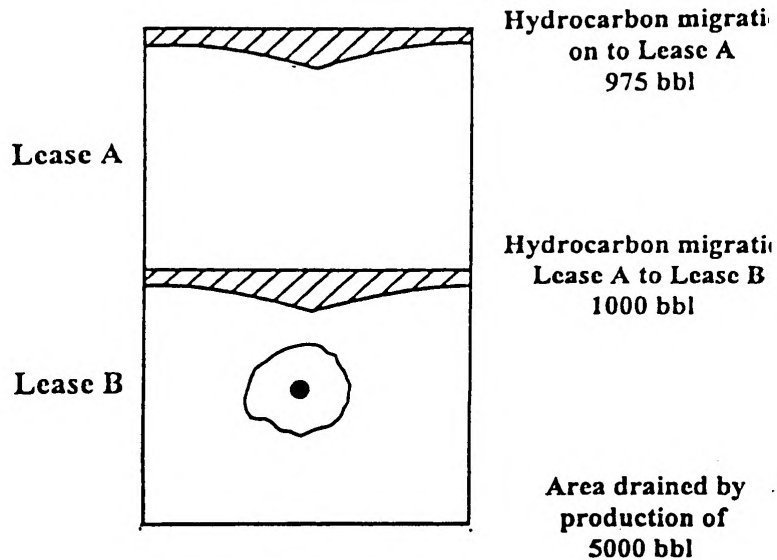
Definition c)



- Well
- Drained Area (Definition a)
- ▨ Location to which hydrocarbons originally under Lease A migrated as a result of production from well on Lease B
- ▨ Drained Volume

FIGURE 4

Definition c)



Hydrocarbon migration on to Lease A
975 bbl

Hydrocarbon migration Lease A to Lease B
1000 bbl

Area drained by production of
5000 bbl

Comparison

Method	Drainage
a	0
b	25 bbl
c	1000 bbl