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Emerald Article: Contaminated properties, trespass, and underground rents

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Contaminated properties, trespass, and underground rents

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Abstract

Purpose – This paper seeks to extend the literature on property damage assessment by incorporating the right of exclusion as a compensable component to damages. The paper aims to go on to illustrate methodologies to estimate as a rent this damage component.

Design/methodology/approach – The authors develop a conceptual framework from which to examine the value of underground storage space with special reference to situations in which migrating contamination from commercial operations have invaded private real property. Specifically they view this invasion as a compensable violation of the right of exclusion. This underground storage analysis uses the three approaches common to traditional appraisal (income, sales and cost) to estimate the value of underground storage caused by migrating contamination.

Findings – Conceptually the paper finds that underground storage can be easily valued with existing appraisal methods. Using contamination scenarios paired with actual market data from the South-Eastern USA, the paper shows an example of each of the three methods for valuation. It concludes by reconciling the estimated values and supply additional issues to consider when valuing underground storage.

Practical implications – Contaminated properties analysis and damages have focused on the right of transfer when estimating damages to real property. Other portions of the bundle of rights also require examination.

Originality/value – This is the first discussion of underground trespass in relation to contaminated property coupled with an empirical example to address the right of exclusion and estimated rents due for use of adjacent properties as a storage facility.

Keywords Underground, Rents, Rental value, Trespass, Storage, Migration, Property rights

Paper type Research paper

I. Introduction

Traditionally the analysis of the effects of contamination as a detrimental condition to real property has focused on the damages to the market value of a property, essentially measuring the partial (or in extreme cases, full) violation of the right of transfer. Neglected or often overlooked is the fact that the migration of the contaminant has also violated the right of exclusion (via trespass) and created a de facto storage facility on the adjacent – and now – contaminated property[1]. This paper presents an approach to valuing this ancillary violation of exclusion.

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In many cases, by increasing the risk of investment and/or by diminishing the utility of the property, contamination decreases the marketability of real property. In situations where the effects on risk and utility are fully internalized by the market, the impact of contamination can be best measured through changes in market prices. However, there are circumstances where price changes – due to the physical nature of the contamination (i.e. underground, invisible particles, etc.), a lack of knowledge about the existence and/or severity of the contamination and other idiosyncratic qualities present in the market – are not immediate or necessarily a reflection of market value and do not immediately show the expected diminution in value (Case *et al.*, 2006). Traditional valuation of the impact of contamination on real estate has only concerned itself with damages to the right of transfer.

Regardless of the impact to the right of transfer (market value), the offsite movement of contamination inherently violates the right of exclusion. By violating this right, the affected properties have been forced into a leased fee agreement with the polluter (the leaseholder) to store the polluter's contaminants. The reaction of the real estate market (changes in sales price) to this storage is irrelevant in terms of the right of exclusion. As a result, this paper is concerned wholly with estimating the value of underground storage as caused by migrating contamination from commercial operations, not diminution to market value due to risk and other negative effects associated with environmentally impaired real property.

This research examines the theory behind this violation and presents a number of methods to estimate the resulting storage value created by the trespass of contamination. The remainder of this paper is divided into the following sections:

- an overview of subsurface rights in the USA;
- a review of the literature on underground storage and rent;
- a case study illustration of underground storage valuation methods to estimate a compensable right; and
- a summary of the application of these methods and potential future research in this direction.

II. Property rights and value in the USA

Ownership of property is often viewed as the possession of a group, or bundle of rights. From an economic perspective, the rights enjoyed by a fee simple owner fall into three categories:

(1) right of use;

(2) right of exclusion; and

(3) right of transfer.

It is important to note that in the USA property itself is not owned, but, rather, the rights of the property are owned. The ability to delineate these rights, and the ability of owners to transfer some or all of these rights voluntarily is a necessary condition for property valuation. In a very practical sense, property rights represent the basis for all economic transactions; by delineating "what belongs to whom under which circumstances," they serve as a dependable source of information and incentives for those engaged in the market (Heine *et al.*, 2002).

The first of the three categories of rights, the right of use, is generally interpreted to mean that the owner may determine how a property will be used, or if it is to be used at all. The right of use is traditionally limited in western culture by both public restrictions, such as eminent domain and police power, as well as private restrictions, such as liens and mortgages. Private restrictions are generally voluntary, and property owners willingly submit to their disutility in exchange for some other economic benefit. For example, a property owner will issue a mortgage to a lender in trade for leverage in the purchase. Also, homeowners commonly purchase in subdivisions with covenants and restrictions in trade for the assurance of uniform property use within their neighborhood. Note, however, that the voluntary acceptance of private restrictions is always in trade for some form of economic compensation. Physical impairments, on the other hand, place a restriction on the right of use without some economic compensation. This is illustrated in potential restrictions which may be placed on the use of real estate due to a physical impairment and which can thus limit the property to something less than its highest and best use.

The second category of rights, the right of exclusion – often called the right of exclusive use or right of exclusive enjoyment – provides that those who have no claim on property should not gain economic benefit from enjoyment of the property. In other words, the right of use is exclusive to the property owner, and any violation of the right of exclusive use typically carries either payment of compensation to the rightful owner or assessment of a penalty. For example, if individual "A" trespasses on land owned by individual "B," then "A" will be guilty of a crime and a possible criminal penalty may be in order, as well as civil damages. Physical impairment by a third party is, in effect, a trespass on property rights, violating the right of exclusion. This right holds true for subsurface (underground) and suprasurface (air) rights in the same manner as surface rights. Society places a high value on the right of exclusion, for good reasons. Exclusion provides that both the current and future benefits of ownership accrue only to the rightful owner and his/her successors and assigns. In the absence of exclusion, the right of use is under constant threat of nullification without just compensation. In an economy without the right of exclusion, property owners would adopt short-term strategies for use, rather than long-term strategies. In an economic sense, this would lead to widespread inefficiency in the allocation of resources. Hence, the right of exclusion carries with it a significant societal good, and thus is a significant socially recognized value (Snare, 1972; Stigler, 1992).

The third category of rights, the right of transfer, provides the owner with the ability to trade one resource for another. Right of transfer, through sub-leasing activities, may be limited to landlord consent or may not be available to leasehold interest depending upon the specifics of the agreed upon contract. In some cases an impairment restricts the right of transfer, and may in fact destroy the right of transfer altogether.

In sum, ownership materializes in the form of property rights, which are delineated into the right of use, right of exclusion, and right of transfer. This bundle of rights applies to all vertical divisions of real property; the surface, subsurface and suprasurface. We now turn to a discussion specifically of subsurface property and its associated rights and uses.

2.1 Subsurface rights

Historically, the physical dimensions of property ownership were considered to extend from the heavens to the depth of the earth (Parisi, 2002). While practicality and modern aviation have effectively limited the extremes of this antiquated system, rights to the subsurface and suprasurface (air) remain valuable today. Evidence of value can be found by examining the markets for these rights.

The two most common transactions involving subsurface rights are underground right-of-way easements and mineral leases. Right-of-way easements are generally granted to companies or public entities involved in providing utility services. These easements allow for shallow, linear, and usually relatively thin, easements to place underground pipes or lines. In many urban areas, right-of-way easements may include traffic and mass transit tunnels. Easements of this design are almost always drafted to be binding for perpetuity and carry with them full use of the property granted.

Mineral leases, on the other hand, generally provide solely for the extraction of minerals and not ownership rights to the land. A property owner granting a mineral lease to another party agrees to forfeit their right to the minerals specified in the lease contract. This may involve solid minerals existing beneath the property, the fugacious (migrating) minerals that may be obtained from extraction operations on site, or both. Such leases may even specify the exact minerals to be extracted, as is common in coal bed leases.

The explosion of the popularity and profitability of using depleted natural gas reservoirs for off-peak storage has added confusion to the rights inherent in a mineral lease. From this, two sets of regulations have developed. Deemed the American Rule and the English Rule, they differ in regards to which party owns the porous space remaining after the extraction of minerals, usually those liquid or gaseous in nature. The American Rule, which governs in most states, holds that the surface owner retains the rights to the geologic formation. On the other hand, the English Rule – followed in a minority of states[2] but nationally in Canada and England – holds that even after complete extraction, the mineral rights holder retains possession of the geologic formation that once contained the minerals that they had rights to extract (De Figueiredo, 2005). Though this division of standards hinders the ease of obtaining underground storage for hydrocarbons, it does highlight the increasing importance, and thus economic value, of subsurface property.

In sum, subsurface rights may be acquired for a number of economic activities including mining, oil and gas exploration, storage, and construction of transportation and communication corridors. The expanding occurrence and wide variety of uses for underground land has rendered subsurface land a vital commodity in much of the nation. Having identified that landowners have rights to their subsurface and that these underground areas have value we now turn to examining a particular violation of subsurface rights: the trespass of underground contaminants.

2.2 Pollution as a trespass

Environmental concerns have been argued before the courts of the land for nearly two centuries. Before the multitude of statutes and regulations that currently protect the bodily health of individuals and the environmental health of public and private real property, legal standing for environmental liability fell under the pretense of common law. Differing from statutory law, which is based on written code, common law springs from the concept of stare decisis, or deference to previously settled decisions. Inside the context of common law, remedy for environmental damages have most prevalently been sought through tort proceedings.

Statutory law, more dynamic and voluminous than common law in regards to environmental protection, has opened the door for much of the courtroom environmentalism of the last half century. Common law, and tort law in particular, however, appears to be making a strong comeback as evidenced by recent court decisions (Hadzima, 2005). These tort claims offer legal standing for issues not specifically covered by the multitude of codes and acts that are often entangled in various levels of government.

Within the realm of tort law, nuisance or trespass claims may be cited for recovery of environmental damages. The two torts, though often working in concert in pollution litigation, are markedly different and may exist exclusively of each other in some situations. Nuisance is described as an interfering action that "annoys, and disturbs one in possession of his property, rendering its ordinary use or occupation physically uncomfortable to him." Trespass, on the hand, is simply the violation of the right of exclusive possession. Trespasses are also distinguished between being permanent or continuous with corresponding degrees of liability attached to each (Aronovsky, 2000).

As our civilization becomes increasingly dependent upon technology that exists at a level too small for recognition by the human eye, many of our long-standing paradigms need to be revisited. The legal field is no exception. Though traditional trespass governed "substantial and direct" invasion of one's property by tangible (visible) agents, much of today's pollution migration (trespass) is carried out by invisible microscopic entities. Moving in gaseous or liquid from, including dissolved solids, these chemical agents are no less harmful that their visible relatives. In fact, since they are often undetectable in the absence of expensive, modern devices they are more likely to be overlooked or mistaken and ultimately ingested, consumed, or spread from place to place.

The expansion of societal knowledge as to the harm of these invaders has not gone unnoticed in judicial chambers. In 1959, the court in Martin v. Reynolds Metal Co. was asked to consider the nature of trespass in relation to migrating fluoride gas. The bench responded by noting that in less sophisticated times a direct, observable intrusion was a sufficient dimensional test, but this has changed to include the unobservable as well. Similarly, in an appeal to the Alabama Supreme Court in the Borland v. Sanders Lead Co., Inc. the court held that trespass may be committed by a "tangible or intangible" agent. More recent cases such as *Bradley* v. *American Smelting and Refining Co. (WA)* and *Stevenson* v. *Du Pont de Nemours and Co.* (CoA) have solidified this precedent (Hadzima, 2005).

As we have observed previously, subsurface property rights possess the same right of exclusive possession as surface rights. Further, nuisance and trespass claims would proceed in the same manner for underground as for torts based on surface actions. Due to the very nature of underground property, one would expect the vast majority of subsurface trespasses to occur in an unobservable fashion, most easily resulting from the migration of microscopic entities.

III. Literature review

In the context of subsurface land uses, storage, though certainly not the predominate use, does hold enormous potential. A review of the published literature on subterranean storage shows it to be far from a novel idea, but, nonetheless, one virtually ignored by the property valuation community.

Literature regarding underground value in the appraisal field is primarily concentrated on oil and gas or other non-fugacious mineral producing properties. This is not surprising considering these are the primary uses of underground land, and thus the primary drivers of subsurface values throughout the country. A limited set of articles addressing storage, easements, and other concerns do exist and will be discussed as well.

Williams (1991) examines the applicability of traditional appraisal methods in valuing oil and gas properties, stating that oil and gas reserves are not only non-renewable, but also differ substantially from property to property, based on a number of criteria, generally geological in nature. The lack of uniformity creates difficulty in finding quality sales comparables, and as a result Williams recommends placing increased emphasis on adjustments. He also notes that oil and gas are commodities that transact in markets which may fluctuate widely, thus rendering future income calculations speculative at best. In light of these circumstances, Williams suggests using both sales comparison and the income approach when valuing mineral properties.

More specific in nature are studies by Cartee (1988) and Baen (1988). Cartee challenges some of the rule of thumb appraisal measures – such as overly general reserve valuation metrics, static per unit commodity values and the use of a single discount rate on production values – that have begun to proliferate among valuation professionals, suggesting instead that a thorough Discounted Cash Flow (DCF) approach should be used. Similarly, Baen (1988) considers a DCF analysis as the proper method to distinguish potential valuation impacts of subsurface mineral discoveries on properties that were previously used solely for surface activities. A follow-up study by Baen (1996) discusses in detail the impacts to surface agricultural values caused by underground oil and gas extraction.

Research by Wampler and Ayler (1998) on precious metals not being mined finds the sales comparison approach, rather than the income approach, as the proper method to value these mineral reserves. They do, however, offer a few caveats:

- sales are often slim, necessitating a wide geographic search for comparables;
- buyers often possess greater knowledge than sellers and therefore an adjustment for knowledge may be necessary; and
- due to the often unknown nature of underground entities a subjective rating of the attributes may be necessary, with the greater the number of attributes equating to a lessened chance of error.

In the underground domain, but apart from mineral properties, the breadth of literature begins to thin considerably with tunnels and storage making up the remainder of the published studies regarding subsurface values. Lea (1994) examines the impact of subway tunnel easements on the overlying land and finds very little impact to the surface values in urban areas. Kilpatrick *et al.* (2007), on the other hand, observe a 20 percent diminution to residential structures located above a freeway tunnel in Seattle, WA.

In regards to underground storage, Davis' (1981) research on the Strategic Petroleum Reserve reports on the cost savings of salt dome versus tank storage (a 75 percent reduction in 1981 dollars). She also notes that developing such facilities averaged about $3.50 per barrel of storage capacity in 1981 dollars. Haines' (2003) study on natural gas storage suggests that constructing gas storage facilities can be quite profitable as the market had been paying about three times the cost to construct for completed facilities. Her analysis shows that such facilities can be built for around $5-$7 million per billion cubic feet of storage area.

Derbes and Dowell's (1988) study on valuation of the Strategic Petroleum Reserve properties in the late 1970s offers the most pertinence in relation to underground storage in the literature to date. Though their study, published in the *Appraisal Journal*, does not give the exact results of their work it does present theoretical and methodological considerations. The paper discusses surface land valuation, highest and best use determinations and the relative theory of value, along with a look at the world energy situation at the time. However, their most interesting observation is that in the case of salt dome storage caverns the improvement is in fact a void, or lack of structure, a consideration which becomes very important when examining underground storage with traditional real estate valuation techniques. Derbes and Dowell (1988) apply the three basic approaches (income, sales comparison, and cost) using a volumetric, per barrel, technique. Their conclusions suggest that the use of relative values and outside physical experts are necessary to properly value unique, special use properties such as salt domes.

More general in approach, a recent study by Pasqual and Riera (2005) investigates the externalities associated with the use of urban underground land and the valuation problems that result from it. The authors note that:

> What is typical of underground land (but not exclusive of it) is that the physical occupation of a unit of space, X implies a decrease in the remaining available space larger than X.

An example being that an underground utility line may be two feet in diameter, but due to future digging and other safety concerns, a buffer must be left around the pipe that is not available to other potential proximate underground uses. In attempting to value urban underground space, the pair found that the underground use is usually not viewed by developers as a separate good and thus its value is not readily apparent in the market place.

As a whole, literature on the valuation of subsurface property, specifically property used as underground storage, is sparse. However, the published studies suggest that, although uncertainties exist due to the physical properties of the underground (i.e. it cannot be seen or measured directly), the traditional appraisal methods of income, sales comparison and cost approaches are sufficient and reliable in valuing underground property.

IV. Valuing underground contamination as storage

The resulting violation of exclusion caused by migrating underground pollution can be valued by examining similar underground storage situation in the local or regional market. As pollution leaves the property of the point-source(s) polluter, it creates a de facto underground storage facility on the property of the adjoining landowners. The polluter is using this land – albeit both without consent and for a use that is not generally legally permissible – and should pay for their benefit of use and violation of the right of exclusion. As a result of these to circumstances – illegality and non-consent of the storage – true market comparables are impossible to find. Instead, market proxies from similar, but not identical, storage situations must be used to gauge the value of the underground storage. Staying within the paradigm of the three traditional approaches to value, incomes, sales, and cost we identify methods to estimate the storage value gained from migrating (off site) contamination; rent (income), market extraction (sales) and replacement or cost to cure (cost)[3]. A discussion of each along with an example calculation follows.

4.1 Empirical case study

For the purposes of the subsequent valuation exercises, we will use two separate scenarios – one of a static plume and one of an actively enlarging plume (aquifer affected) – to illustrate the application of valuation methods (Figure 1). In scenario 1 we assume that the static[4] underground plume of contamination is 50 acres in areal size, 12 feet in depth and

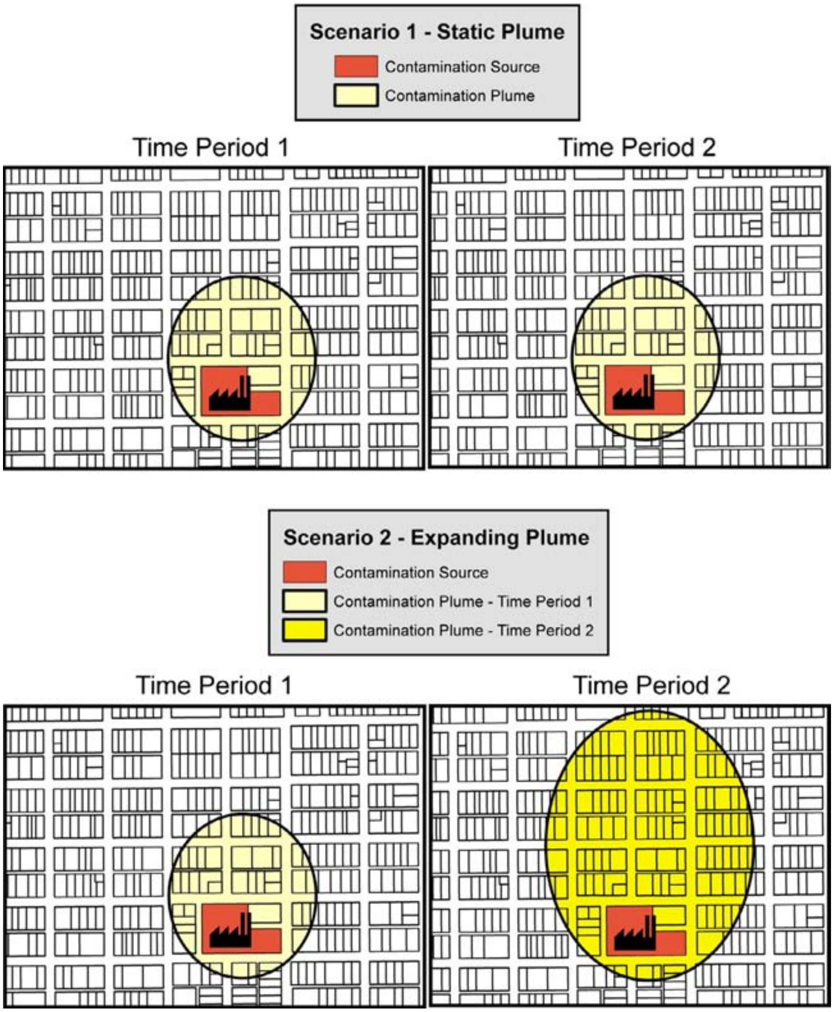

Figure 1.
Contamination scenarios

located in an area with a soil porosity of 20 percent[5]. In scenario 2 – the actively enlarging plume – we assume that the plume begins with the same dimensions as scenario 1 but that it grows at 1 areal acre per year with all remaining assumptions identical to scenario 1. For purposes of final value reconciliation we assume that the contaminant is expected to naturally attenuate – has an economic life of – 250 years (essentially a permanent, incurable contamination), but we will also show the value of underground storage for each scenario under each valuation method at economic lives of ten, 25, 50 and 100 years[6].

4.2 Rent method

The storage of underground pollution is essentially the use of the underground space by another party for their (economic) benefit. If one desired to procure storage space, or any space (retail, industrial or residential) a willing lessor must be offered an acceptable price for the use of their property for a specified period of time. In simple terms, this is a lease; the polluter holding the leasehold interest and the affected property owner the leased fee interest. Payments are expressed as a lease rate.

In the appraisal profession, properties which are leased out to another party are known as income producing properties. Valuation of such properties is principally based on the net present value of the future stream of expected rental incomes derived through direct capitalization or yield capitalization through a DCF analysis with a terminal capitalization rate. Estimating the value of underground storage (a leased right of occupancy and use) can be done in a similar manner. In order to apply the rent valuation method several other factors need to be determined. These are a lease rate, a discount rate and the economic life.

4.3 Determining a lease rate

While the rental market for underground space is not as active or as commoditized as the market for office space or apartments, subterranean space, nonetheless, transacts. Finding applicable market data will vary significantly based on the location, both regionally and locally, of the subject site. Researchers in the southeast and western USA will find plentiful the number of oil and gas leases, those in the Northeast and upper Midwest are more likely to find transactions involving natural gas storage facilities. In dense urban areas, underground uses are likely to involve the built environment such as parking, utility and right-of-way easements, and structural reinforcements.

When searching for applicable lease transactions it is important to remember that underground storage, or any other underground use, is just that, the right to use the underground area. Thus, although a case may involve the underground storage of methyl tert-butyl ether (MTBE), one need not find a lease involving the uncontained underground storage of MTBE, as significant difficulty will likely be encountered since this manner of storage is both environmentally unsound and illegal. As stated by Anderson (2010), "Finding identical transactions is impractical if not impossible and, as such, data that is otherwise similar becomes the objective". Proxies can be used effectively – though adjustments may be warranted – in the place of identical storage leases. Market research can be used to determine past appreciation (depreciation) of market lease rates and adjust future rate estimates accordingly.

4.4 Discount rate

The discount rate represents the level of risk of actual payment associated with the cash flow or cash flow stream. If the cash flows in question are considered a certainty because of the unlikely ability to remediate or the natural attenuation of the contaminant is long term, the cash flow stream will continue over an extended period of time. Coupled with a low likelihood of default by a corporate trespasser and the common accounting of a lease as an obligation or debt a discount rate reflecting the cost of debt to the trespasser is appropriate. For this example, we selected a corporate bond rate of 6 percent as the cost of debt[7]. In other cases the discount rate may vary depending on the specifics of the situation.

4.5 Economic life

A conventional DCF analysis operates with an assumption of a prescribed economic life for the property, resulting in a limited calculation of future benefits based on the assumed life of the property. At the end of this time period, a terminal capitalization rate is applied to represent the remaining value of the property after the income stream has ceased to be calculated[8].

The economic life of an underground storage facility (composed of migrating pollution) is a function of the physical attributes of the pollutant, the geophysical properties of the underground strata, and remediation feasibility and/or potential. A pollutant which will naturally attenuate in 20 years creates an underground storage facility with an identifiable economic life[9]. On the other hand, chemicals which do not naturally breakdown may warrant a greatly extended economic life and thus a longer stream of future revenues. Constrained aquifers and/or very deep pollution may create a situation in which remediation activities are not physically possible or economically feasible, also necessitating extending the economic life and negating any cost to cure estimates.

4.6 Rent method example

For these scenarios the market research determined an adjusted per acre underground storage lease rate of $500 per year, and a time adjustment of 3 percent per year representing the long term inflation rate. The storage lease rate is a midpoint estimate from a collection of underground storage leases of petrochemicals gathered from market participants in the Southeastern USA. Table I – rent method example, outlines a basic DCF showing these metrics. Figure 2 shows the present value of the income stream given over a selected set of economic life assumptions (lease durations). As one can see, for the static plume (scenario 1) the value becomes asymptotic near $830,000 at approximately 150 years in the future. For the expanding plume (scenario 2) the value reaches an asymptote at approximately $1,400,000 after considering 250 years of future underground rent. In the situation we are considering in this paper – an economic life of 250 years – the estimated underground storage value for scenario 1 is $830,000 and for scenario 2 a value of $1,400,000. Table I shows potential storage values under a range of different economic life assumptions. As Table I also highlights a growing plume obviously equates to more "storage" space and therefore as the economic life of the contaminant increases the premium of the expanding plume over the static plume increases as well.

4.7 Sales comparison method

Rather than renting the storage space containing the migrating contaminants, this method assumes that the polluter purchases the rights to a storage space capable

Plume size (year 1)	50 acres	
Plume growth	1 acre per year	
Annual lease rate (year 1)	$500	
Annual lease rate increase (%)	3	
Discount rate (%)	6	
	Present value of the underground storage	
Economic life of contaminant	*Scenario 1*	*Scenario 2*
10 years	$207,970	$225,704
25 years	$426,794	$516,589
50 years	$635,004	$872,711
100 years	$786,132	$1,231,540
250 years	$832,697	$1,401,301

Table I.
Rent example

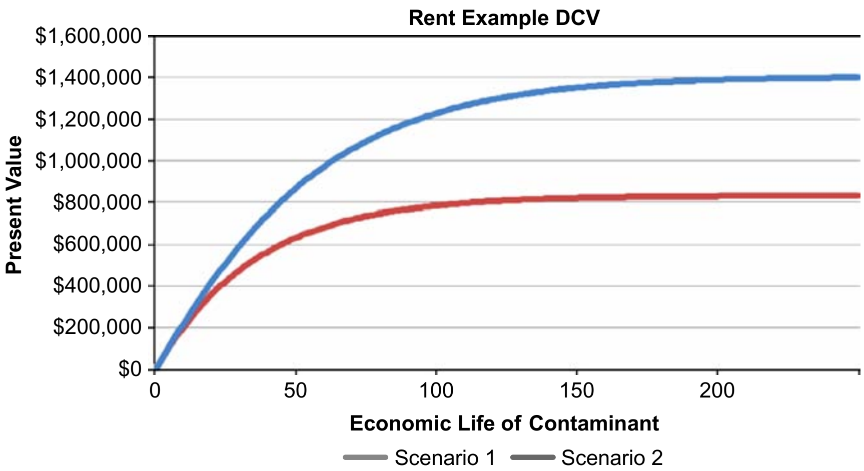

Figure 2.
Rent method PV time plot

of enclosing the contamination plume. Similar to a traditional sales comparison approach, we examine sales of properties used for underground use or storage. Adjustments are made to sales to represent locational differences and changes in market conditions. It is important to remember that the market price for underground land may need to be derived as a residual, as sales often involve the entire property (the surface and suprasurface rights as well). A simple review of current land sales can aid in identifying the going surface land price, though underground rights usually accompany the surface land in most transactions. As a result, often times it is better to conduct a matched pair analysis between properties with similar surface, but differing subsurface characteristics in order to determine the ratio of the value between the surface and subsurface land[10].

In the case of non-migrating contamination event (scenario 1), the sales comparison method can be approached as it traditionally would – by finding comparable market transactions and making adjustments as required. For this analysis the market research determined a storage price per acre of $20,000 per year. This $20,000 figure is derived from actual market transactions of properties with depleted natural gas aquifers or salt caverns and strata which are mined to create underground storage space. These sales were located in the Southeastern USA, concentrated in Louisiana. Simply multiplying the adjusted price per acre by the size of the contamination plume will result in a storage value estimate for a non-migrating contamination plume.

On the other hand, in a case (scenario 2) where the plume is continually expanding the sales comparison approach will function somewhat like an income approach. As the plume expands each year, additional property is affected. From a sales comparison standpoint this means that each year as the plume grows the contaminator must purchase addition storage space. Conceptually, the current purchase (represented by the extent of plume now) plus the imminent future purchases (future cash flows) represents a stream of income, albeit one of sales prices not rents. We have differentiated the sales comparison from the income approach due to issues of ownership for the storage space over time. In an income approach situation, the property owner retains title to the storage space but simply lets it out for use to the polluter. Conversely, in a sales comparison situation the polluter simply buys the entire storage space for a one time price. The physical aspects of the contamination should guide the analyst or appraiser as to which method to prefer – short-term pollution is likely to be an income approach problem, whereas storage of pollution with no removal or attenuation potential is likely best valued with a sales comparison approach.

In the case of the expanding plume (storage space), we must use a cash flow analysis to place a current value on the future purchases of storage space. We have used a 3 percent per year inflation rate and the 6 percent discount rate mentioned above.

Table II – sales comparison method – shows the results using a basic DCF with these metrics. In this example, the estimated storage value created by the trespass in scenario 1 with a sales comparison approach is $940,000. In the case of an expanding plume the storage value (the value of the initial purchase of storage space plus the discounted value of future necessary purchases as the plume expands) limits out at just under $1.6 million with an economic life assumption of 250 years, along with alternative economics lives. Figure 3 shows the value differences between the static and expanding plume scenarios.

Plume size (year 1)	50 acres	
Plume growth	1 acre per year	
Sales price per acre (year 1)	$20,000	
Annual price rate increase (%)	3	
Discount rate (%)	6	
	Present value of the underground storage	
Economic life of contaminant	*Scenario 1*	*Scenario 2*
10 years	$943,396	$1,090,904
25 years	$943,396	$1,265,963
50 years	$943,396	$1,432,532
100 years	$943,396	$1,553,434
250 years	$943,396	$1,590,686

Table II.
Sales comparison method

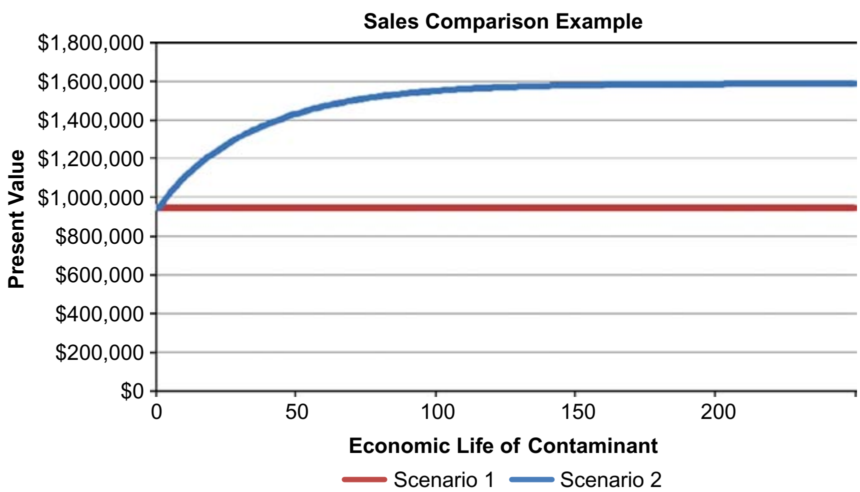

Figure 3.
Sales method PV time plot

4.8 Replacement cost method

The replacement cost method estimates the cost to properly dispose of the current volume of contaminated water (and potentially, soil). The most common method of chemical waste disposal in the USA is through the use of disposal wells[11]. These wells, also referred to as injection wells, are constructed for the purpose of injecting waste products, usually liquid in form, into deep underground aquifers. While many large production facilities maintain on-site disposal wells, open-market wells, which accept pollution from willing customers, also exist. As a result, another way to judge the storage value of underground contamination is to estimate the cost to dispose of a similar volume of contaminants on the open market.

Valuing the potential cost estimate involves determining the volume of polluted water or storage space occupied by the migrated contaminant and multiplying it by the injection well disposal cost. If the contamination plume is static, that is not expanding; this may be a one-time cost figure. The same would be true for a plume for which remediation is physically possible. In the instance where a plume is both growing and remediation is impossible, each passing year necessitates additional "proper" disposal costs, and thus a DCF analysis is required.

Again, we are assuming that our contamination event has the physical properties previously described (note the plume acreage has been converted to acre feet of water) and that remediation is not possible. Our market research returned an adjusted storage (disposal) of $1.00 per barrel (7,588 barrels per acre foot). We derived this cost per barrel metric from reconciling a collection of petroleum production waste disposal leases in the Southeastern USA. On average, oil producers in the area pay $1.00 per barrel to dispose of excess waste water from their extraction process. Table III – replacement cost method outlines a basic DCF showing these metrics. Much like the sales comparison example, a static plume in the replacement cost method only equates to a single, one-time payment. In this case that value is approximately $875,000. For the expanding plume, the value becomes asymptotic around 150 years in the future at about $1.5 million (Figure 4).

Plume size (year 1)	50 acres	
Plume growth	1 acres per year	
Aquifer depth	12 feet	
Soil porosity (%)	20	
Barrels in an acre foot	7,758	
Barrels to dispose (year 1)	930,960	
Barrels to dispose each year after	18,619.2	
Disposal rate (year 1)	$1 per barrel	
Annual price rate increase (%)	3	
Discount rate (%)	6	
	Present value of the underground storage	
Economic life of contaminant	*Scenario 1*	*Scenario 2*
10 years	$878,264	$1,015,588
25 years	$878,264	$1,178,561
50 years	$878,264	$1,333,630
100 years	$878,264	$1,446,185
250 years	$878,264	$1,480,865

Table III.
Replacement cost method

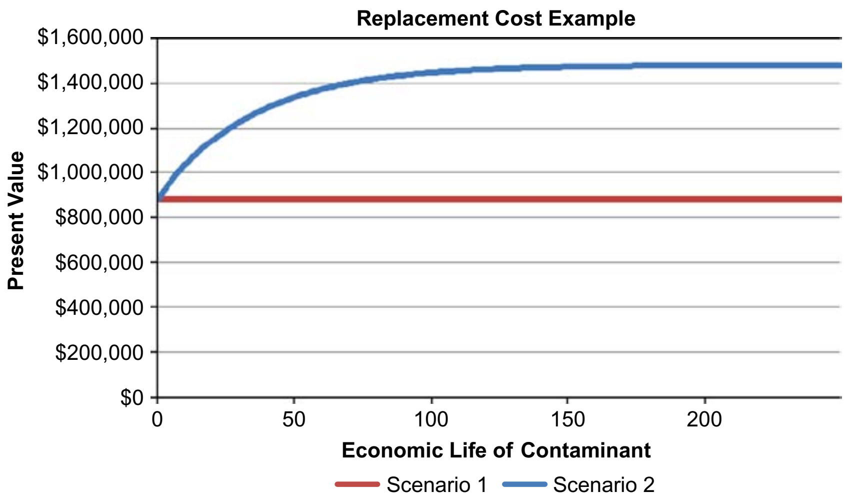

Figure 4.
Replacement cost method PV time plot

V. Reconciliation and suggestions

In the examples above we considered two separate scenarios of underground contamination one static and one expanding. Although we presented a range of economic life calculations, for the purposes of reconciliation here we deal only with the original assumption described at the beginning of section 4: a contaminant economic life of 250 years representing an asymptotic result. Under this assumption the valuation methods suggest a range in value from $$833,000 to $943,000 for the non-expanding plume (scenario 1) with a midpoint value of approximately $900,000 (Table IV – summary of methods). In the case of the expanding plume (scenario 2) the values range from $1.4 million to $1.6 million, centered around $1.5 million. As Table IV illustrates, in cases where contaminants have very long attenuation schedules the rent, sales, and costs methods are likely to be complimentary and can be used to reconcile an underground storage value. However, in cases where attenuation (economic life) is relatively short (< 50 years), the rent method is likely to be the preferred method since the lifespan of the contamination functions more similar to a traditional lease rather than an outright sale. Additionally, as the figures illustrate, the values for contamination events with very long natural attenuation periods become asymptotic after a few hundred years or less (depending on the difference between the inflation and the discount rates), meaning that the DCF calculations can be truncated at some point in the future.

	Scenario 1 – static plume			Scenario 2 – expanding plume		
Economic Life	Rent	Sales	Cost	Rent	Sales	Cost
10 years	$207,970	$943,396	$878,264	$225,704	$1,090,904	$1,015,588
25 years	$426,794	$943,396	$878,264	$516,589	$1,265,963	$1,178,561
50 years	$635,004	$943,396	$878,264	$872,711	$1,432,532	$1,333,630
100 years	$786,132	$943,396	$878,264	$1,231,540	$1,553,434	$1,446,185
250 years	$832,697	$943,396	$878,264	$1,401,301	$1,590,686	$1,480,865

Table IV.
Summary of calculations

Reconciling these value estimates can be done a number of ways depending on the relative strength of the market data and the researcher's comfort level with each of the individual methods. In many instances, due to lack of data or unique characteristics of the contamination event, all methods may not be applicable in every underground storage situation. Plume movement, regional location, local markets, and geophysical characteristics of the land may all influence the choice of which method is most appropriate to use and the calculation metrics involved in the chosen method. The level of detail regarding the contamination, especially in cases of invisible underground pollution, is highly dependent on the physical science experts (either governmental or privately contracted) working on the case. As such, the science will often dictate the methods and reconciliation processes used in underground storage valuation.

VI. Conclusions

The migration of underground contaminants represents a violation of the right of exclusion and may represent a significant storage value to the polluter. This storage value can be estimated through the use of the traditional approaches to value. This paper illustrated a rent, sales value, and replacement cost approach. In most cases a direct market for underground pollution storage will not exist, in these instances proxies for such storage can be found in the market with the necessary adjustment being made based on the unique characteristics of the contamination plume, such as chemical compound, geophysical properties, and remediation potential. Additionally, valuation metrics, methods, and reconciliation procedures will vary based on regional locations and local markets. In sum, the value gained by the unlawful trespass – a violation of one of the fundamental rights of property ownership – can be estimated using a variety of storage valuation techniques.

This analysis can be expanded to take into consideration the time of discovery and how the time of usage is measured. For instance does a trespasser owe compensation for the estimated time the trespass started until it was cured or discovered to be incurable? Or does the time measurement start at the time of discovery?

Each jurisdiction may have different legal interpretation of trespass and tort law. If contamination reaches a moving aquifer other state laws or legal case decisions would also need investigation in relation to water rights. Also specifics of the analysis may hinge on whether the jurisdiction uses the "American Rule" or "English Rule" because of implication as to who owns any underground facility and whether a facility replacement is required for an estimation of damages. In sum, this paper is a first step at addressing the complex issue of valuing underground storage in a migrating contamination context.

Notes

1. A visible or measurable discharge of a contaminant from a given point of origin (Appraisal Institute, 2008).
2. Alabama, California, Illinois, Indiana, Kentucky, Louisiana, New York, Ohio, Oklahoma and Wyoming.
3. The cost approach can be thought of as a method to terminate the existence of storage rather than a use value.

4. In reality no plume is static the porosity of the soil will allow for movement, we are simplifying under the assumption that the trespasser or monitoring agency will intervene to prevent growth.
5. The ratio, usually expressed as a percentage, of the volume of voids in a material to the total volume of the material, including the voids (Appraisal Institute, 2008).
6. Practitioners may terminate compensation at no more than 50 years based on economic life of improvements.
7. Corporate bond and other market rates can be found in Federal Reserve rate table H15 at: www.federalreserve.gov/releases/H15/data.htm
8. The terminal cap rate would need to infer whether the property will continue to be impaired or remediated.
9. The economic life may also be calculated by estimating when a clean-up will result in the elimination of storage.
10. As mentioned prior the underground usage may not be recognized explicitly, and can be a residual to other uses. There is a need to find comparables where a use of the underground is part of the transaction rather than the existence of a potential underground use.
11. Incineration is another potential form of disposal. We do not cover incineration costs in the paper.

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